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13. ABSTRACT

Obstetric outpatients, attending the prenatal clinic at the Wright-Patterson AFB Medical Center, were frequently required to wait in excess of one hour to see a doctor even though their consultations are scheduled by appointments. Two causes that contribute to this waiting time are the uncertainty as to the number of doctors that will be available for the clinic and the attempt to eliminate doctor idle time. A computer simulation model was developed to enable experimentation with twelve different appointment systems. The simulation model takes into account four random occurrences (patient arrival time, consultation time, arrival of walk-in patients and number of doctors available) which characterize this particular clinic. The appointment system, recommended for immediate implementation, schedules 10 patients for the first appointment and 5 patients each 10 min. interval thereafter. This recommendation is based on a normally distributed patient arrival time, about a mean of 11.14 mins. before the appointment time, a gamma distributed consultation time with a mean of 6.86 mins., a 40 min. mean inter-arrival time for walk-in patients and from one to six doctors available. The resulting average patient waiting time and average doctor idle time was 17.73 mins. and 2.82 mins. respectfully.

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OUTPATIENT SCHEDULING

A SIMULATION APPROACH

THESIS

GSA/SM/71-3 Ronald K. Hall
Capt. USAF

OUTPATIENT SCHEDULING
A SIMULATION APPROACH

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology

Air University
in Partial Fulfillment of the
Requirements for the Degree of

Master of Science
by

Ronald K. Hall, B.S.I.E.
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Graduate Systems Analysis

June 1971

Preface

This thesis is my attempt to analyze the problem of patient waiting times and doctor idle times and to reduce both by structuring an appointment system designed to lessen the effect of the causes of the problem. Due to the limited amount of time available for data collection and analysis, a number of assumptions were required which may not satisfy all readers of this thesis. However, the resulting simulation model can easily be altered, by interested readers, in further studies to test the effects of different assumptions.

I would like to extend an apology to those medically knowledgeable individuals, who find reason to read this study, for my limited understanding of the medical profession which in several circumstances may result in my flagrant use of medical terminology. Writing a thesis that is easily understandable to both the analyst with little medical background and the physician with little formal analysis background, presents a problem of finding the suitable balance between the two fields. Ultimately, of course, such a balance can only reflect my personal preference as a systems analyst. My contacts with the staff of the hospital clinics has confirmed my previously developed feelings of respect and admiration for the dedicated and frequently over-worked military physician.

The systems analyst can find areas for application of his skills in practically every field of endeavor. The hospital/clinic scope of operation is no exception. Although many of the existing problems within the Medical Center are recognized by the staff, there is no one individual with the time and ability to perform the required analysis to remedy those problems. "A systems analyst in every Air Force Medical Center" should be the motto for the future.

I would like to express my appreciation for the assistance and guidance which was received from Major Ronald J. Quayle, thesis advisor, and Lieutenant Colonel Thomas Murray Jr. and Major David L. Belden, thesis readers. I'm also indebted to Doctor William E. Calihan and his entire staff for their friendly cooperation during my numerous data gathering sessions at the OB-GYN clinic. I would also like to express my appreciation for the invaluable assistance received from Mr. Robert F. Bachert in writing and debugging the simulation program.

Finally, I am indebted to my wife who has withstood the lengthy OB waiting times throughout the course of two pregnancies and whose inspiration served to guide me to this particular thesis topic.

Ronald K. Hall

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Abstract

Obstetric outpatients, attending the prenatal clinic at the Wright-Patterson AFB Medical Center, were frequently required to wait in excess of one hour to see a doctor even though their consultations are scheduled by appointments. Two causes that contribute to this waiting time are the uncertainty as to the number of doctors that will be available for the clinic and the attempt to eliminate doctor idle time. A computer simulation model was developed to enable experimentation with twelve different appointment systems. The simulation model takes into account four random occurrences (patient arrival time, consultation time, arrival of walk-in patients and number of doctors available) which characterize this particular clinic. The appointment system,recommended for immediate implementation, schedules 10 patients for the first appointment and 5 patients each 10 min. interval thereafter. This recommendation is based on a normally distributed patient arrival time, about a mean of 11.14 mins. before the appointment time, a gamma distributed consultation time with a mean of 6.86 mins., a 40 min. mean inter-arrival time for walk-in patients and from one to six doctors available. The resulting average patient waiting time and average doctor idle time was 17.73 mins. and 2.82 mins. respectfully.

I. INTRODUCTION

The United States Air Force (USAF) is currently in the process of combining the capabilities of computer science with medical center operations in hopes of developing a more timely and integrated medical service. The recent need for improved methods of handling hospital information is explained in a National Center for Health Services Research and Development, HEW, Report NCHS-RD-69-1, prepared for the Federal Hospital Council, quote:

> "The ultimate solution to the hospital information problem may not be the development of more usable time-sharing systems but rather the development of a capability which can tie together discrete information handling capabilities as they develop at their own speed within the several hospital services. We, therefore submit that at least one possible solution to the organizational problem which seems to be the crux is to find some way to bring many discrete activities together as they occur under their own rate of development."

This emphasis on the development of hospital information systems (H.I.S.) has caused a concerted effort by Wright-Patterson Air Force Base (WPAFB) personnel from the Medical Center, Aerospace Medical Research Laboratory and Air Force Logistics Command to initiate actions to establish a H.I.S. for the WPAFB Medical Center.

At a joint meeting in November 1970, it was determined that the first step towards a complete H.I.S. for the Medical Center should be the implementation of a pilot project to schedule outpatient appointments. In view of the interests evidenced in the scheduling of outpatient

appointments, this facet of the hospital complex was chosen as the subject of this thesis. Waiting time in outpatient departments has been characterized as follows: "... the waiting time of the patient is indeed a central, if not the central, problem in all outpatient departments" (Ref 9:18). A sizable part of this waiting time can generally be attributed to inefficiencies in appointment systems. Therefore, this thesis is concerned with examining various appointment systems with the objective of reducing patient waiting times and doctor idle times. In pursuit of this objective, one of the tools of the systems analyst, the technique of computer simulation, was applied.

Definitions

The following terms, several of which are taken from Principles of Hospital Administration (Ref 5) and Hospital Industrial Engineering (Ref 7), are defined for the purpose of this thesis.

Arrival Pattern- The statistical distribution of arrivals of patients. The average number of arrivals per unit time is referred to as the arrival rate, and the time between two arrivals is referred to as the inter-arrival time.

Block Appointment System- System whereby groups of patients are scheduled at different times throughout the clinic session. This system ranges from having all patients, expected to be seen during a specific clinic, scheduled at the beginning of the clinic to having groups scheduled to arrive every 30 minutes of the clinic session.

Centralized Appointment System- System whereby appointments for all clinics are made at one central location.

Consultation Time- The sum of all the time a patient holds the doctor's attention. Includes preliminary medical records scan, writing prescriptions, entries in medical records, etc.

Decentralized Appointment System- System whereby each individual clinic makes its own appointments.

Doctor Idle Time- Sum of time between the doctor's arrival time at the clinic and his last appointment

time in which he is not consulting due to no patients being available to be seen.

Emergency Outpatient- A person given emergency or accident care for conditions determined clinically, or considered by the patient, as requiring immediate physician services.

General Outpatient- A person given diagnostic or therapeutic services on an outpatient basis for other than an emergency condition, and who has not been directly referred for such services by his attending doctor.

Individual Appointment System- System whereby each patient is given a separate appointment time. Appointments are usually scheduled at intervals equivalent to the average consultation time.

Inpatient- A person who is registered in the hospital to be given general or emergency diagnostic, therapeautic or preventive health services provided through a hospital facility.

Interactions- The effects which queue length has upon arrival pattern, service pattern, and queue discipline.

Modified Centralized Appointment System- System whereby some clinics are on a centralized appointment system and others use a decentralized appointment system.

New Outpatient Visit- Outpatient visit by a person who appears for the first time, or within a specific period of time.

No Show- Outpatient who fails to keep a previously scheduled appointment.

Outpatient- A person given general or emergency diagnostic, therapeutic, or preventive health services provided through a hospital facility and who, at the time, is not registered as an inpatient in the hospital.

Outpatient Department- That section of the hospital with allotted physical facilities, regularly scheduled hours, and personnel in sufficient numbers assigned for established hours, to provide care for patients who are not registered as inpatients while receiving physician services.

Outpatient Visit- The arrival of a person at the outpatient department of the hospital to receive diagnostic or therapeutic services.

Patient Waiting Time- Period between a patient's arrival at the clinic and the beginning of his consultation with the doctor.

Queue Discipline- The manner in which the next patient to be served is selected.

Referred Outpatient- A person referred directly to the outpatient department by his attending medical practitioner for specific diagnostic or treatment procedures, for other than an emergency condition, and who will return to the practitioner for further care and disposition.

Repeat Outpatient Visit- Outpatient visit by a person who appears within a specified period of time subsequent to a new outpatient visit.

Semi-Block Appointment System- System which utilizes aspects of both the individual and the block appointment systems.

Service Pattern- The statistical distribution of time required for service, as well as to the number of customers which can be served simultaneously. The average number of customers which the facility is capable of serving per unit time is referred to as the service rate.

Walk-in Patient- A patient arriving at a clinic without having an appointment. Used in this thesis to refer to emergency and referred patients collectively.

Conditions Which Prompted The Study

The WPAFB Medical Center has recognized that the services it can and should render to the Air Force community can be exemplified in the quality of its care to the outpatient. The recognition of this fact comes from a simple matter of numbers. The average number of inpatient admissions per month is approximately 700 while the outpatient visits surpass 30,000 per month. This awareness of the need for effective and efficient outpatient care insured hospital wide cooperation throughout the course of this thesis.

When given the test words "outpatient department" in a free association test, most laymen would undoubtedly reply "waiting" (Ref 10:605). A widely observable feature of hospital outpatient clinics is the disproportionately long

time which patients are obligated to wait compared with the average period devoted to actual medical examination or consultation (Ref 1:185). A direct result of these long waits is overcrowding of patient waiting rooms. The WPAFB Medical Center is no exception to these conditions. Several times during the collection of data for this thesis, patients were observed standing in waiting rooms due to the overcrowded conditions. One particular observation revealed 55 patients waiting in the Obstetric-Gynecologic (OB-GYN) clinic, which has an outpatient waiting room seating capacity of 42. During anotner observation day, obstetric patients had a mean waiting time of 53.9 minutes which culminated in an examination which lasted approximately 6.8 minutes.

The disadvantages of congestion like this within the clinic are: (1) the attitude and cooperation of the patient is affected by the conditions existing in the waiting room (Ref 8:38) (2) knowing that there are a large number of waiting patients, doctors may tend to hurry patients through the medical consultation (3) waiting rooms can become overcrowded, resulting in patients waiting elsewhere in the clinic area and (4) to some patients excessive waiting represents a loss of working time as pointed out by Villegas (Ref 13:52).

A number of factors have lead to this congestion in the WPAFB Medical Center clinics. A series of interviews with administrators, doctors and appointment clerks revealed the following prominent causes:

(1) Advances in medicine and new methods of treatment have enabled patients, previously requiring hospitalization, to be treated as outpatients. Also, hospital patients are being discharged earlier and are completing their treatment as outpatients.

(2) An increase in the population being served by the Medical Center caused by an increase in the number of WPAFB personnel and an increase in the number of retired personnel settling in the Dayton area.

(3) The walk-in patients tend to disrupt the orderly flow of patients, scheduled to be seen during any specific clinic session, due to their unpredictable arrivals.

Bailey contends that an over-riding consideration with most appointment systems is that the consultant be kept fully occupied. Large queues of patients are often allowed to build up in order to avoid the possibility of the consultant ever having to wait for a patient (Ref 1:185). The large number of people utilizing the WPAFB Medical Center has forced this same consideration on the various clinics. Not that doctor idle time represents a loss of income, as may be the case in the civilian clinic, but because idle time represents greater numbers of patients waiting to be given appointments sometime in the future in the military clinic.

Statement Of The Problem

The "apparent" inefficient outpatient scheduling techniques in use at the WPAFB Medical Center result in lengthy patient waiting times which in turn exert constant pressure on the physicians to make hurried medical examinations and diagnoses in order to see all the scheduled patients.

Objective

To develop and analyze, through the use of computer simulation, various techniques for scheduling outpatient appointments in order to minimize patient waiting times without greatly increasing doctor idle times and thereby reduce the pressure on the physicians caused by large numbers of waiting patients.

Scope Of Research

The problem of developing an efficient outpatient appointment system varies from clinic to clinic within the same hospital due to the characteristics of the particular clinic and the population being served. Therefore, to allow a thorough analysis of the number of variables that affect appointment systems, it was decided to concentrate on a single clinic. This approach may limit the validity of the conclusions of this research to the clinic studied but the results should prove applicable to all similar clinics, at least within the Air Force medical system.

The decision to concentrate on the OB-GYN clinic was influenced by several factors. The OB-GYN clinic currently uses two of the most popular forms of appointment scheduling - block appointments and individual appointments. Patient waiting times in this clinic are currently excessive, as can be seen in Table I. Millward suggested that it

Table I
OB-GYN Waiting/Consultation Times*

Type of clinical session being attended	Patient waiting time on day of appointment	Length of routine patient appointment
GYN	30 mins.	20 mins.
New OB	60 mins.	20 mins.
Prenatal Clinic	60 mins.	6 mins.
Post-Partum Clinic	20 mins.	20 mins.
Complicated Prenatal	15 mins.	20 mins.

* Extract from survey conducted by Medical Center personnel (28 August to 30 September 1970).

would be reasonable if 50% of patients were seen within fifteen minutes of the appointment times and 75% within a half hour; not more than 3% should have to wait more than one hour (Ref 6:605). Another factor influencing the decision to do the analysis on the OB-GYN clinic is the fact that doctors in this clinic are on call during clinic hours to handle baby deliveries thus disrupting clinic sessions and contributing greatly to outpatient waiting times. This is a peculiarity of this clinic only. Finally, this clinic has one of the largest number of outpatient visits per month. During the period from July 1970 to

December 1970, the average monthly numbers of outpatients visiting this clinic were 1168 OBs and 1661 GYNs.

Method Of Approach

To examine the various methods of scheduling OB-GYN appointments in search of a more efficient procedure, it was decided to simulate several scheduling methods under conditions that currently exist in the clinic. The definition of simulation best explains why this method of obtaining a solution was used. Simulation means the process of conducting experiments on a model of a system in lieu of either (1) direct experimentation with the system itself, or (2) direct analytical solution of some problem associated with the system (Ref 2:1). Direct experimentation with the clinic appointment system was not feasible due to the risk of compounding an already conjested system. A direct analytical solution could not be obtained from a mathematical expression due to problems of walk-in patients, no shows and varying numbers of doctors available for clinic sessions.

The problem of the outpatient clinic can be analyzed in terms of a basic queueing process:

Input source (calling population)- The OB-GYN outpatient arriving as a scheduled appointment or walk-in appointment.

Queue- Outpatients occupying the clinic waiting room and waiting for service.

Service discipline- Patients are selected for consultation or examination in order of appointment times.

Service mechanism- The clinic consultation by a doctor.

Patient arrival patterns and doctor consultation patterns were developed from observations conducted at the various OB and GYN clinic sessions during a 3 week period in January 1971. An inter-arrival time distribution for walk-in patients was assumed based on past records of numbers of walk-in visits per day. A distribution for the number of doctors available during the clinic hours was assumed based on approximations attained from clinic staff personnel.

These four random variables (arrival rate, consultation rate, walk-in rate and doctor availability) were then used to develop a computer simulation program that would simulate a prenatal afternoon clinic session consisting of 120 outpatients. The 120 outpatient figure compares favorably with the average number of patients actually seen during a current prenatal clinic session. Various methods of scheduling patients were then introduced and results of the simulated clinic sessions using each method of scheduling were tabulated and analyzed.

II. DESCRIPTION OF PRESENT OB-GYN OPERATIONS

The OB-GYN clinic is located on the first floor of the USAF Medical Center, WPAFB, Ohio. The mission of the clinic is to provide obstetric and gynecologic care to active duty military, retired military and their dependents. GYN patients attend the clinic sessions when they develop gynecologic problems. The number of visits depends on the nature of the problem. OB patients are scheduled for clinic sessions throughout their pregnancy. They are given one appointment per month during the first seven months of pregnancy; appointments every two weeks during the eighth month; and weekly appointments in the ninth month.

The clinic staff is made up of the following numbers of personnel:

4 Staff physicians
2 Interns
1 Nurse clinician
1 Registered nurse
2 Licensed practical nurses
1 Sergeant (NCOIC)
1 Receptionist
3-5 Red Cross volunteers

Schedules and Appointment Systems

The various outpatient clinics are conducted as shown in Fig. 1. A normal day for the doctors runs from 0800 hours to 1700 hours (Monday, Wednesday and Friday mornings surgery starts at 0715 hours). The day consists basically of:

0800 to 0830 - Rounds (visits to inpatients)
0830 to 0900 - Consultations plus paperwork dictations, etc.

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
0900 to 1200	0900 to 1200	0800 to 1130	0930 to1200	0900 to 1200
New OB physicals No specific doctor 20 min. appt's. Simple GYN surgery	GYN appointments Specific doctor 20 min. appt's.	New OB class (lead by RN) Most complicated GYN surgery 1000 to 1200 GYN appointments	GYN appointments Specific doctor 20 min. appt's	Complicated pre-natal clinic Specific doctor 20 min. appt's. Simple GYN surgery
1300 to 1630	1300 to 1630	1300 to 1430	1300 to 1500	1300 to 1630
GYN appointments Specific doctor 20 min. appt's.	GYN appointments Specific doctor 20 min. appt's.	Prenatal clinic No specific doctor 6 min. appt's. 1430 to 1630 Post-partum clinic	GYN appointments Specific doctor 20 min. appt's. 1500 to 1630 Tumor board and professional staff conference	Prenatal clinic No specific doctor 6 min. appt's.

Fig. 1. Obstetrics-Gynecology Clinic Schedule

0900 to 1200 - Clinic sessions
1200 to 1300 - Lunch
1300 to 1630 - Clinic sessions
1630 to 1700 - Closing rounds

Staff physicians are On-Call in the hospital 3½ days/week and are off one ½ day per week following their night On-Call in the hospital. During the day On-Call, they cover Labor and Delivery, see inpatient referrals and confer with Interns on their cases.

The OB-GYN clinic is a user of the Medical Center modified centralized appointment system. All GYN appointments are made through the central appointment desk while OB appointments are made through the clinic itself.

Complicated prenatal and GYN patients are scheduled on an individual appointment basis with specific doctors. The appointment interval in each case is 20 minutes. Patients attending the new OB physical clinic or the prenatal clinic are scheduled in 15 minute blocks of from 10 to 15 patients depending on the patient load. No doctor is specified for these patients and all staff doctors (including the doctor On-Call) and Interns see patients during these clinic sessions.

The OB patient flow chart is shown in Fig. 2. Records for these patients are maintained at the clinic itself rather than in the Medical Center records room. During the observation period patients were required to wait at three different stations. A patient arriving at the clinic is seated in the waiting room until her name is

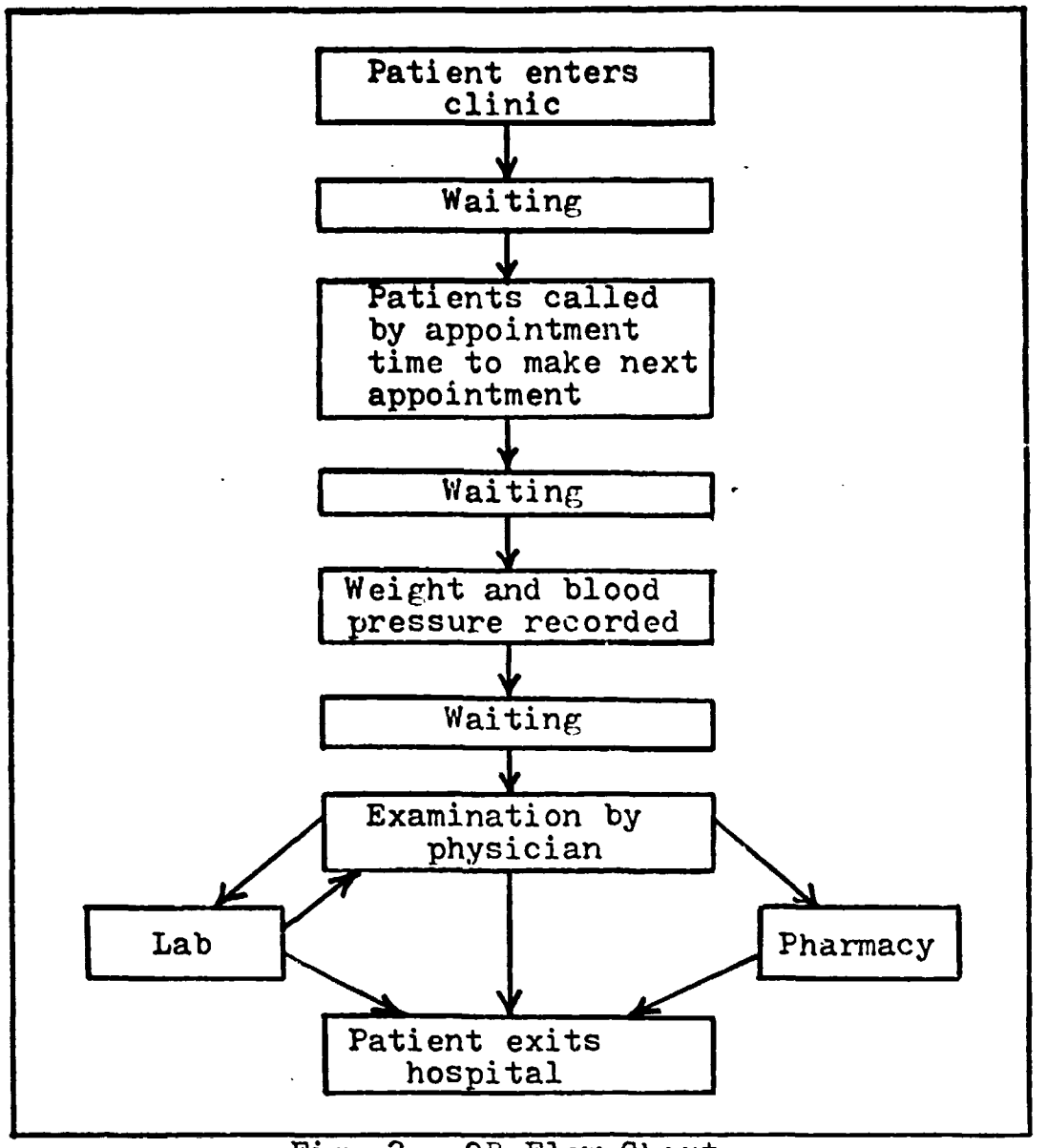

Fig. 2. OB Flow Chart

called from the appointment schedule. Then she joins the queue at the reception desk to make her next appointment and receive her medical records. From the reception desk she proceeds to join the queue at the weight and blood pressure recording station. When her weight and blood pressure has been recorded, she returns to the waiting room to await her turn to see a doctor. The waiting time at the

first two queues often becomes excessive because there is little coordination between the reception desk and the recording station, i.e., the receptionist calls people from the waiting room at a rate faster than the recording station can process them. The cause of the first two waiting periods seems to be the result of the desire to rush patients through the preliminary stages even though a wait will still be required before doctor consultation. Unless the patient is a new outpatient, there is no patient paperwork required.

The GYN patient flow as shown in Fig. 3 is less "assembly-line" oriented. Records for these patients are maintained in the Medical Center records room. The patient is often required to pick up her records from the records room after she arrives at the clinic if her records have not been forwarded to the clinic in accordance with established administrative procedures.

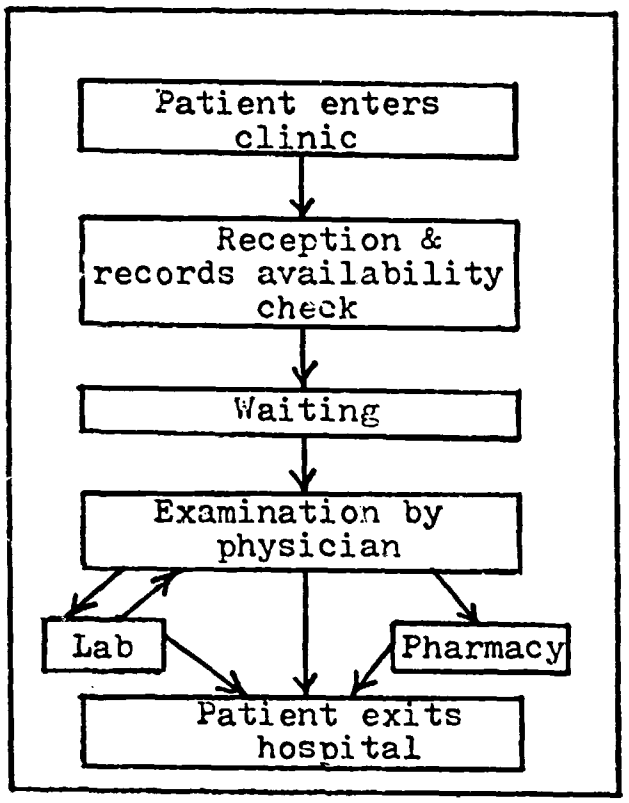

Fig. 3. GYN Flow Chart

Data Collection and Analysis

During a three week period from 11-29 January 1971, observations were made at the OB-GYN clinic to determine arrival patterns and service patterns. In addition to observations, a number of patients were requested to record four times as they attended the clinic session. These four times were appointment time, arrival time, consultation start time and consultation finish time.

The OB and GYN arrival times were recorded separately to see if there was a significant difference of mean arrival times which might be attributed to the different types of appointment system or population being sampled. Since patient arrival times depend on a large number of independent random variables, the arrival pattern was assumed to be normally distributed with respect to the appointment times. OB patient mean arrival time was 10.88 minutes before the appointment time with a standard deviation of 10.1 minutes. The corresponding mean and standard deviation for GYN patients was 11.66 minutes and 11.59 minutes respectfully.

The assumption was made that the patient arrival pattern is independent of the clinic characteristics such as patient waiting time, appointment system in use and clinic attended. Since the OB and GYN clinics schedule their patients in different manners and they have different patient waiting times, a t-test of significance of difference between their mean patient arrival times was conducted to validate the assumption (Ref 2:401).

OB Patients	GYN Patients
$\bar{X}_1 = 10.88$	$\bar{X}_2 = 11.66$
$S_1^2 = 102.07$	$S_2^2 = 134.38$
$N_1 = 100$	$N_2 = 50$

Calculating the t-distribution statistic using

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{(N_1 - 1)S_1^2 + (N_2 - 1)S_2^2}{N_1 + N_2 - 2}}\sqrt{\frac{1}{N_1} + \frac{1}{N_2}}}$$

$$= .424$$

The tabulated value for t with $N_1 + N_2 - 2 = 148$ degrees of freedom at the .05 significance level is 1.96. Since .424 is less than 1.96, the null hypothesis that there is not a significant difference between means failed to be rejected. This means that even though the data for the OB and GYN arrival patterns was collected during different clinics, with unlike appointment systems and different patient waiting times, the arrival distribution is essentially the same. Therefore, the assumption, that the arrival pattern is independent of the circumstances surrounding the clinic operation, can be made allowing one arrival pattern to be used throughout the simulation experimentation.

The combined arrival pattern is shown in Fig. 4. A Chi Square goodness of fit test (Ref 2:424) revealed that the assumption of a normally distributed arrival pattern

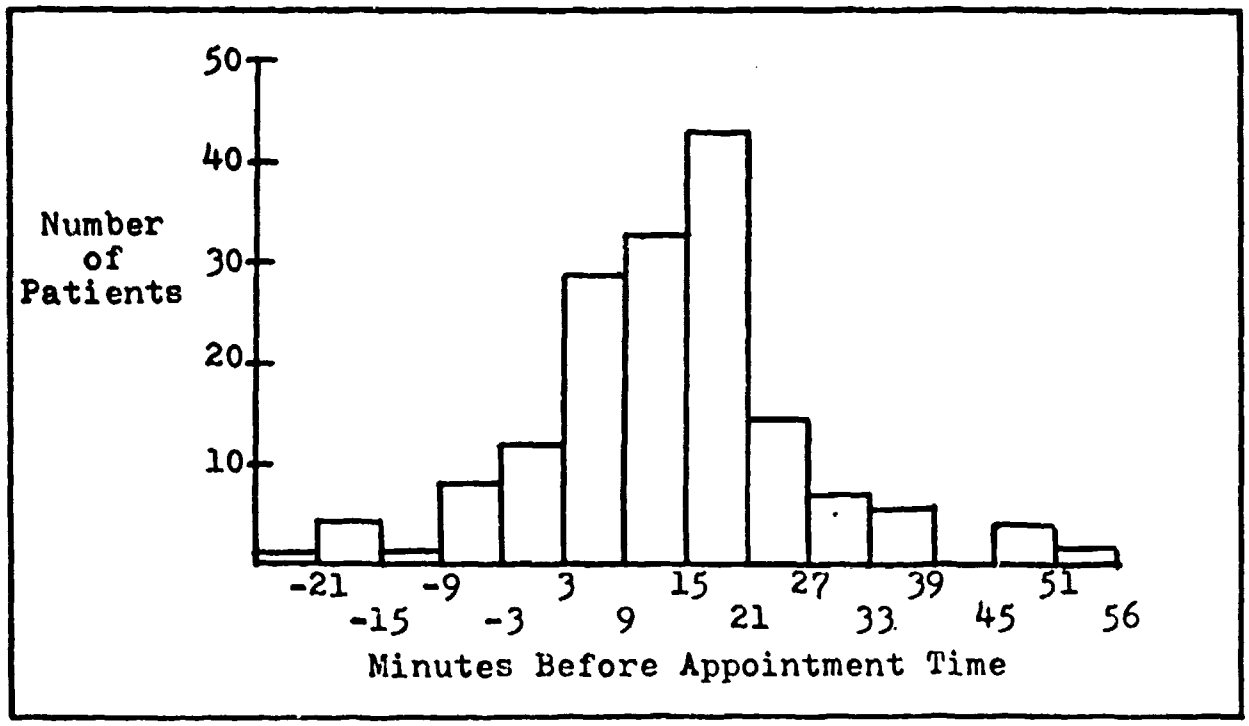

Fig. 4. Arrival Pattern

was acceptable (See Appendix A). The mean and standard deviation of this combined sample was 11.14 minutes and 11.71 minutes respectfully.

The doctor service (consultation) time sample distributions are shown in Figs. 5 and 6. The service times were assumed to have a gamma distribution based on previous studies conducted by the Nuffield Provincial Hospitals Trust, the University of Bristol and Bailey (Ref 1:187). A verification of this assumption was performed by using a computer program to conduct a Kolmogorov-Smirnov (K-S) goodness of fit test (Ref 2:436) on the two sets of data. A copy of the program and partial results are contained in Appendix B. The .01 level of significance was used for this test. The largest difference statistic

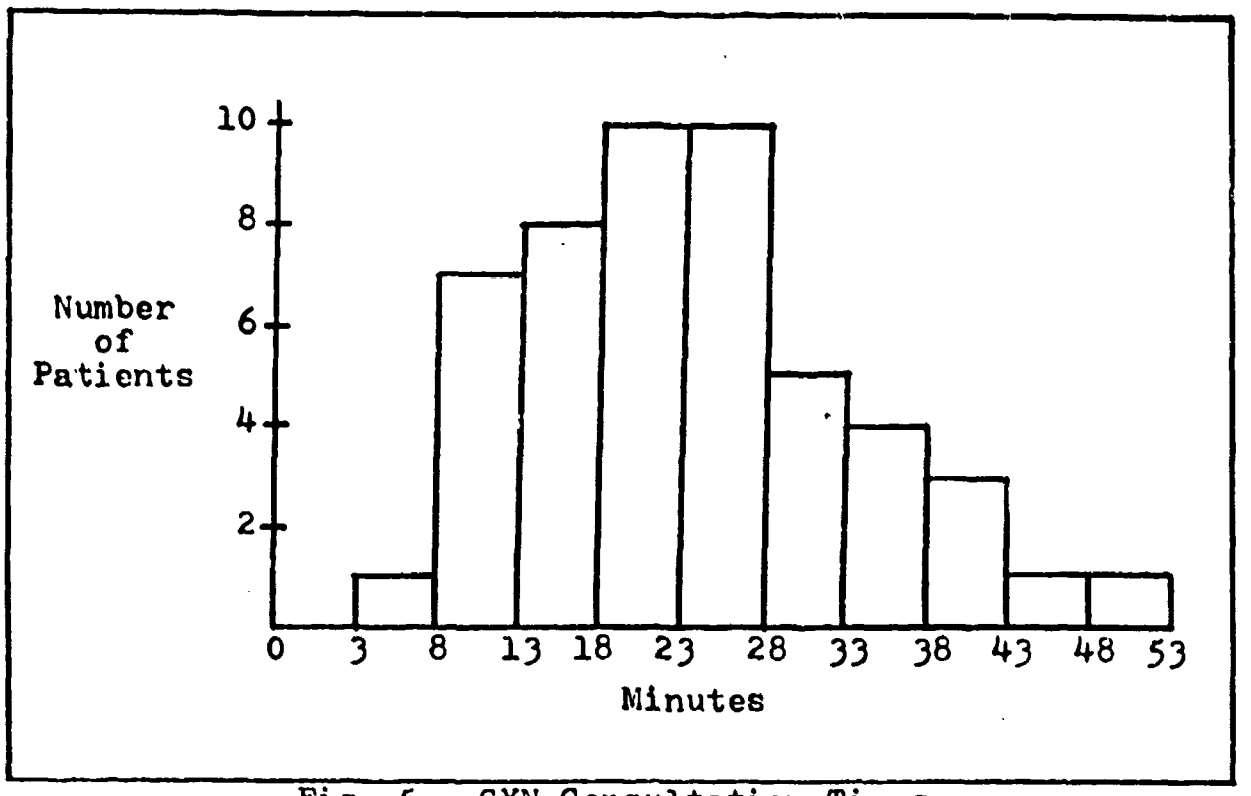

Fig. 5. GYN Consultation Times

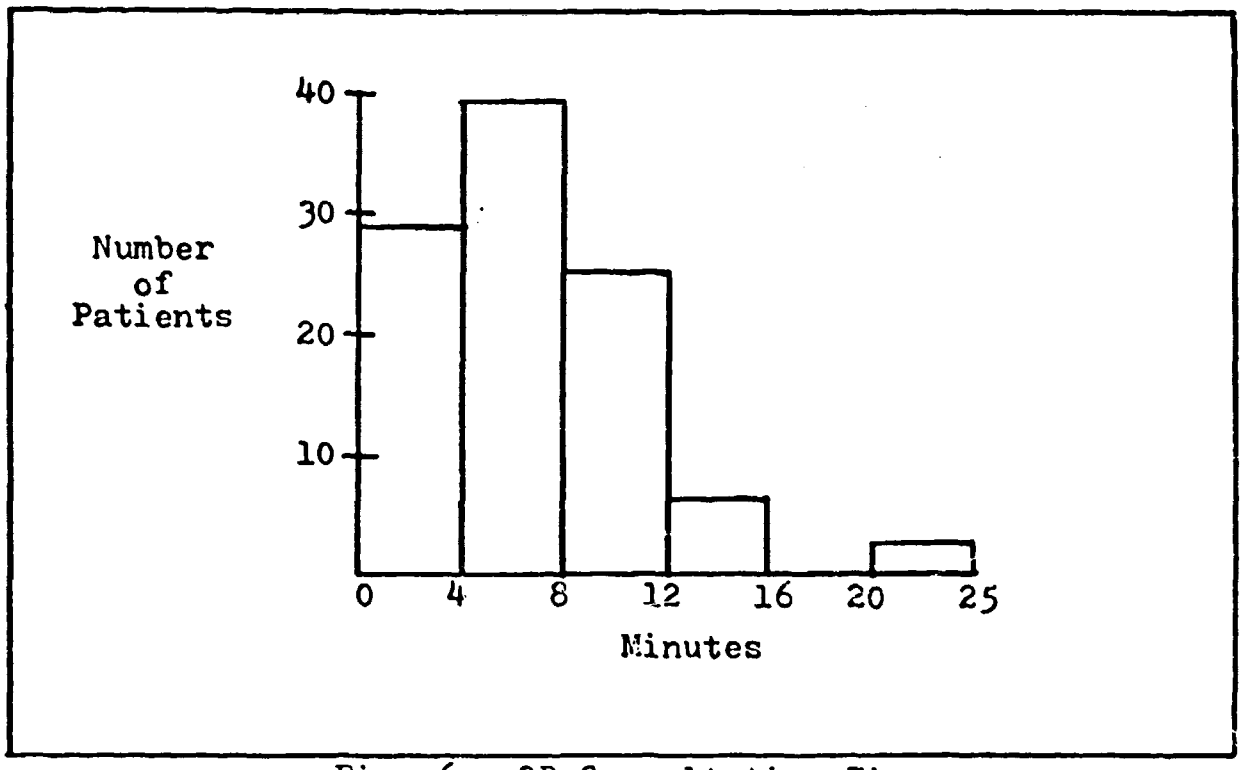

Fig. 6. OB Consultation Times

obtained from the OB times approached that of the maximum K-S statistic allowable for two explainable reasons: (1) data error and (2) affect of queue on doctor consultation times. Due to the relatively short OB consultation time (mean = 6.86 min.), the data recorded by the patients revealed a large number of 5 minute entries, some of which, in all likelihood should have been rounded to 4 or 6 minutes. This clustering of data points at the 5 minute intervals was a common occurrence throughout the data collection period. The second reason for the statistic becoming quite large is the result of the pressure on the doctor to shorten consulting periods as a reaction to the building queue. This caused the sample data to contain an abnormal number of consulting times less than 5 minutes. This occurrence should be eliminated by an appointment system that reduces waiting times.

The results of the simulation model are relatively insensitive to the assumption of a gamma consultation time distribution because of the short OB consulting times. Although the studies conducted by the Nuffield Provincial Hospitals Trust, the University of Bristol and Bailey have verified this gamma distribution assumption, an assumption of a normally distributed consultation time would not significantly change the results of the simulation model. However, the gamma distribution was accepted and used for the purpose of this thesis.

A review of the past six months attendance records at the clinic revealed an average of 12 walk-in patients per day. The walk-in patient was assumed to have an exponentially distributed inter-arrival time since no pattern existed between walk-ins and specific time periods. A mean inter-arrival time of 40 minutes was determined based on an 8 hour clinical day. The following assumptions were made in arriving at the exponential inter-arrival time:

(1) the probability that a walk-in patient arrives during the time interval $(t,(t+\Delta x))$ is $(1/40)\Delta x$.

(2) the rate of walk-ins is independent of time

(3) the probability that more than one walk-in will occur during a small time interval is effectively zero.

Lack of sufficient data prohibited the calculation of a consultation time distribution for walk-in patients. The consultation time was assumed to be 20 minutes in length based on the fact that most walk-in patients are GYN (mean consultation time = 21.6 mins.) in nature.

The no show rate is usually a scheduling problem as discussed by Hofmann and Rockart (Ref 4:37). They concluded that the overall no show rate at the Massachusetts General Hospital was in the vicinity of 21% of the total patients scheduled by previous appointments. Observations at the Medical Center OB-GYN clinic revealed no problem existing with the no shows. No shows amount to less than 2% of the total appointments. During an interview with one of the staff physicians, this peculiarity was mentioned. He

confirmed that from his past experience in civilian clinics the military dependent has "excellent discipline" in comparison. A contributing factor to this discipline is the difficulty of getting an appointment to the clinic, i.e., if an appointment is missed, an undesireably long wait is required until the next appointment can be scheduled.

Probably the greatest single factor contributing to the OB waiting times is the uncertainty involving the availability of doctors for the clinic sessions. With a delivery rate of more than 100 babies a month, it is not unusual for doctors to be called away from clinic sessions to perform deliveries. Compound this with temporary duty trips, leaves, illnesses and meeting requirements and you have waiting time problems, especially for the OB clinic sessions where patients are not scheduled by specific doctor. The present appointment system is constructed with the idea that all six doctors will be in attendence. However, based on averaged estimates received from the OB-GYN staff, the clinic operates with the following numbers of doctors available the percentages of time indicated:

One doctor only	2%
Two doctors only	10%
Three doctors only	31%
Four doctors only	31%
Five doctors only	24%
Six doctors	2%

Initial analysis of the data revealed few waiting time problems associated with the GYN clinic sessions. The

mean waiting time (in respect to appointment times) of outpatients attending the GYN clinic was 16.8 minutes. The reasons for this relatively short waiting time for the GYN clinic are:

(1) patients are scheduled for a specific doctor, thus the doctor On-Call has no scheduled patients and if a doctor will be absent, his patients for that day are cancelled

(2) patients are scheduled at intervals approximately equal to the mean consultation times (20 minutes in this case)

(3) no attempt is made to "over-schedule" a doctor to prevent idle time.

Since the "real" waiting time problems involve the OB clinic, the simulation model and the remaining sections of this thesis will deal with the OB clinic exclusively.

III. ALTERNATIVE APPOINTMENT SYSTEMS

"A doctor can see only a specified number of patients within a given time. Granted that this is so, the arrival of those patients might just as well be regulated by an arrangement of appointments that benefits both the patient and the doctor"(Ref 12:65). The "ideal" appointment system would be one in which patient arrivals coincided exactly with the completion of the previous patients consultation period (overlooking the need for a certain amount of necessary paperwork on both the patients and doctors cirriculum). This "ideal" system is impossible to attain however, due to uncertainties such as variable lengths of consultation periods and unpunctuality of patient arrivals. The search for a "near ideal" appointment system centers around minimizing both patient waiting time and doctor idle time while recognizing, that to a certain extent, they are conflicting objectives.

The various types of appointment systems in existence today can be arranged on a continuum as seen in Fig. 7.

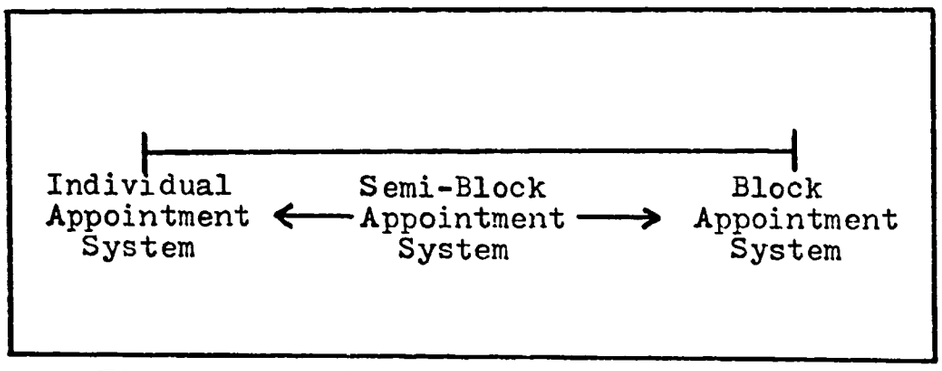

Fig. 7. Appointment System Continuum

From the patient's viewpoint, an individual appointment system is highly desirable. The waiting time of the patient is minimized and congestion is reduced in the waiting rooms. The disadvantage of this system is that due to no shows, lateness of patient arrivals and inability to exactly specify length of consultation periods the amount of doctor idle time can become vary large. Therefore, while being highly desirable for the patient it is normally undesirable from the hospital administrator's point of view.

The block appointment system resulted from the attempts of hospital administrators to eliminate the disadvantages of the individual appointment system. This system insured that the doctor's idle time would be minimized but in so doing resulted in extremely long patient waiting times, i.e., if 15 patients were scheduled for a morning clinic, all 15 would be given appointment times at the start of the clinic session. A direct result of this system is the regular occurance of conjestion in waiting rooms.

The optimum scheduling system for most clinical situations lies somewhere between the extreme ends of the appointment system continuum. These types of appointment systems, referred to as semi-block appointment systems, attempt to integrate the advantageous aspects of both the individual and the block appointment systems. An initial small block of patients might be scheduled at the beginning

of the clinic session to off-set no shows and late arrivals and then a form of the individual appointment system might be used for subsequently scheduled patients. Once again it should be reiterated, that the arrival pattern must be designed to accomplish two main objectives: (1) reduction of waiting time to a minimum and (2) preclusion of significant doctor idle time.

Since there are an infinite number of possible appointment combinations, the selection of alternative appointment systems, to be tested by the simulation model, had to be based on personal judgement, knowledge of the characteristics of the OB clinic and practicality of administering the appointment system. The number of alternative appointment systems tested was limited by the time available for simulation. However, should it become desirable to simulate additional systems, the simulation program package can be obtained from Mr. Bachert, WPAFB(AMRL/HES), ext. 55409.

It was determined that the alternatives should be developed with no less than a 10 minute interval between scheduled appointments to allow for easy administration of the system. This appointment interval is practical from the patient's viewpoint also as it does not require her to remember that she has an appointment at 1317 hours, 1402 hours, etc. Table II outlines the first five appointment systems that were simulated. These appointment systems schedule blocks of varying numbers of patients at 10 minute intervals.

Table II
Alternative Appointment Systems (1-5)

Time	Number of patients scheduled				
	Appt. System 1	Appt. System 2	Appt. System 3	Appt. System 4	Appt. System 5
1300	4	5	5	6	6
1310	4	4	5	5	6
1320	4	5	5	6	6
1330	4	4	5	5	6
1340	4	5	5	6	6
1350	4	4	5	5	6
1400	4	5	5	6	6
1410	4	4	5	5	6
1420	4	5	5	6	6
1430	4	4	5	5	6
1440	4	5	5	6	6
1450	4	4	5	5	6
1500	4	5	5	6	6
1510	4	4	5	5	6
1520	4	5	5	6	6
1530	4	4	5	5	6
1540	4	5	5	6	6
1550	4	4	5	5	6
1600	4	5	5	6	6
1610	4	4	5	5	6
1620	4	5	5	6	
1630	4	4	5	4	
1640	4	5	5		
1650	4	4	5		
1700	4	5			
1710	4	4			
1720	4	3			
1730	4				
1740	4				
1750	4				
	120	120	120	120	120

Since these five appointment systems are all based on a similar structure, it was decided that other appointment systems should be simulated to see the effect of varying that basic structure. Table III illustrates the variations that were simulated. Appointment systems 6, 7 and 8 contain an initial block of 10 patients to establish

a reserve to reduce doctor idle time at the beginning of the clinic session. The remainder of schedules 6, 7 and 8 are structured like appointment systems 1, 3 and 5 respectfully. Appointment systems 9, 10 and 11 extend the appointment interval to 20 minutes and increase the size of each block of patients.

Table III
Alternative Appointment Systems (6-11)

	Number of patients scheduled					
Time	Appt. System 6	Appt. System 7	Appt. System 8	Appt. System 9	Appt. System 10	Appt. System 11
1300	10	10	10	8	10	12
1310	4	5	6			
1320	4	5	6	8	10	12
1330	4	5	6			
1340	4	5	6	8	10	12
1350	4	5	6			
1400	4	5	6	8	10	12
1410	4	5	6			
1420	4	5	6	8	10	12
1430	4	5	6			
1440	4	5	6	8	10	12
1450	4	5	6			
1500	4	5	6	8	10	12
1510	4	5	6			
1520	4	5	6	8	10	12
1530	4	5	6			
1540	4	5	6	8	10	12
1550	4	5	6			
1600	4	5	6	8	10	12
1610	4	5	2			
1620	4	5		8	10	
1630	4	5				
1640	4	5		8	10	
1650	4					
1700	4			8		
1710	4					
1720	4			8		
1730	4					
1740	2			8		
	120	120	120	120	120	120

Although it was evident that the appointment system in use during the observation periods was unsatisfactory, that system had not been changed simply because no one individual on the staff had the time to make the necessary adjustments to insure a better system would be implemented. This appointment system (number 12), whereby 15 patients are scheduled by appointment every 15 minutes, was included in the simulation for demonstration purposes and to aid in validating the simulation model.

IV. The Simulation Model

The simulation model was written in FORTRAN IV (rather than in a simulation language) to facilitate its understanding by any individual with a basic computer programming background. The flow diagram and complete program are included in Appendix C. The specific clinic session simulated was a one-half day OB prenatal clinic of 120 scheduled patients. The 120 patient figure is approximately the number of OB patients that currently attend this clinic session. No attempt was made during the course of this thesis to analyze this patient load in regards to facilities and doctors available at the clinic. In essence, the simulation is of a multi-server queueing system since there are from one to six doctors conducting the prenatal clinic session and the patients are not scheduled to see any specific doctor.

Basic Assumptions

The following basic assumptions were needed to enable the development of the simulation model:

(1) Consultation times do not vary between doctors or between doctors and interns. Although in most clinical situations this fact does not hold, the routine nature of the prenatal clinic results in little variation between doctor consultation times.

(2) The waiting room has sufficient space for an unlimited buildup of the queue.

(3) Arrival distribution is not affected by the queue length, i.e., patients don't turn away when queue length is long.

(4) Queue length does not affect consultation times. Although during the observations of the present operation of the OB clinic there was a tendency for consultation times to shorten as the queue lengthened, this practice seems questionable from a medical viewpoint alone. An effective appointment system should tend to eliminate any cause for varying the length of consultation times.

(5) Patients will not refuse to see a particular doctor in order to wait for another.

(6) Patients will be selected from the queue on an earliest appointment time basis. In case of two or more patients in the queue with the same appointment times, the one with the earliest arrival time is selected first.

(7) The number of doctors available for clinic sessions will vary between one and six.

(8) Walk-in patients join the queue with an appointment time equal to their arrival time and their consultation time is fixed at 20 minutes since most of the walk-ins have gynecologic problems.

(9) The IBM 360 pseudorandom number generator generates perfectly random numbers.

Starting Conditions

The simulation model starts at time = 0 minutes with the first appointments scheduled for time = 60 minutes. All doctors available for the start of the clinic session begin consultations at time = 65 minutes. This 5 minute delay allows first patients to accomplish preliminary weight and blood pressure checks prior to starting their consultation. It also provides a simulation for the "traditional" unpunctual doctor arrival as stated by Welch and Bailey (Ref 11:1105-1106). In respect to the appointment systems outlined in Chapter III, time = 60 minutes simulates 1300 hours in "real" time.

Time Increment Method

The method of advancement of simulation time is a form of the variable increment method (Ref 3:159). Although no clock is utilized to keep track of the current time in the model, the simulation advances from event to event on the basis of earliest event time, i.e., if event "A" time = 80 minutes, event "B" time = 90 minutes and event "C" time = 78 minutes, the simulation will process event "C" first.

Process Generators

The process generators are the mechanisms used in the simulation model by which the random variables (patient

arrival times, doctors available, walk-in times and consultation times) involved in a system are represented.

Patient arrival times. The patient arrival time at the clinic was determined by subtracting a normally distributed variate with an expected value of 11.14 minutes and standard deviation of 11.71 minutes (obtained from actual data) from the patient's scheduled appointment time. The variate was generated through the use of the IBM 360 subroutine GAUSS. The normal distribution was truncated at -20 minutes and +70 minutes. This truncation assured that more than 99% of the possible arrival times are being included in the simulation model. (referring tc theoretical dist.)

D ctors availability. The number of doctors available was determined from the discrete cumulative distribution shown in Fig. 8. A random number between 0 and 1 was

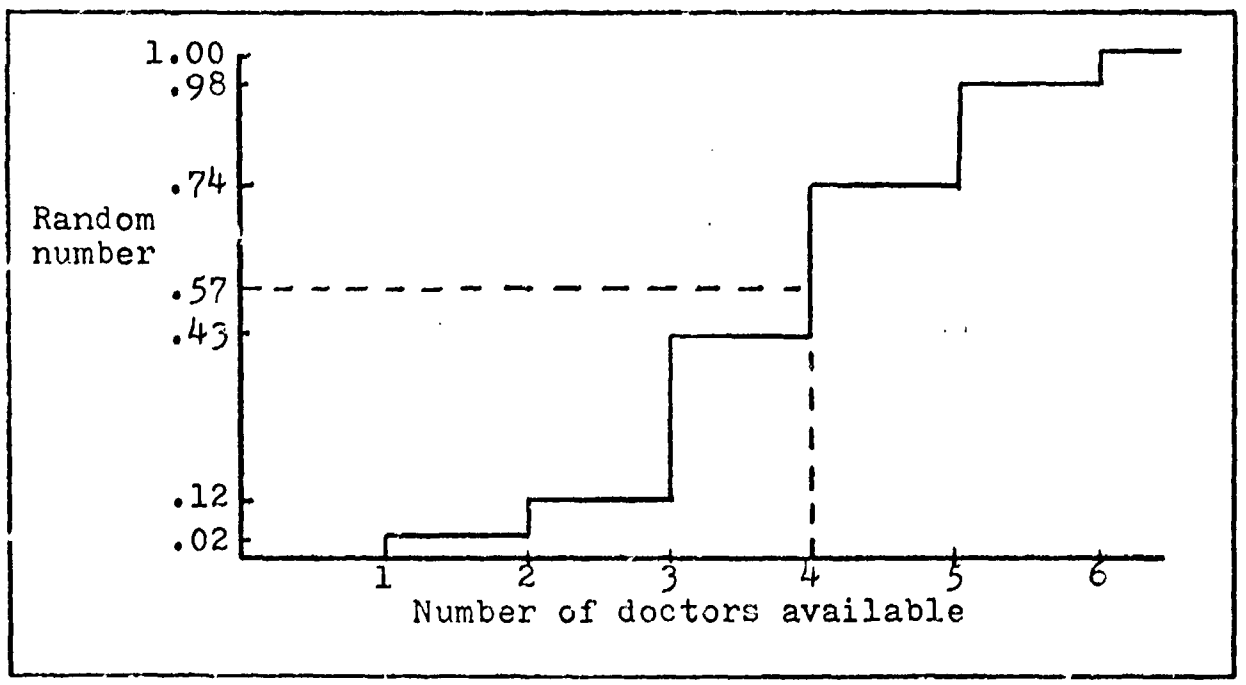

Fig. 8. Doctor Availability Distribution (based on clinic staff approximations)

generated and the number of doctors available was determined from the cumulative distribution, i.e., if the random number was .57, there were 4 doctors available for that period of the clinic session. A new random drawing was arbitrarily accomplished every 30 minutes to simulate varying numbers of doctors being available.

Walk-in times. The walk-in patient times were determined by the use of the inverse transformation technique. The walk-in inter-arrival times were calculated from the following formula:

$$x = -EX(\log r)$$

where

x = time between arrivals
EX = mean inter-arrival time (40 minutes in this simulation)
r = random number, uniform on [0,1]

The first walk-in occurs at time = 60 + x_1 minutes with subsequent arrivals at intervals of x_2, x_3, etc.

Consultation times. The method of generating random consultation times utilized the uniform distribution of numbers between 0 and 1 in the same manner as the generation of doctors available. The subroutine used to conduct the K-S test in Appendix B was modified to compute the cumulative distributions of 100 points between 1 and 25 minutes of a gamma probability density function with shape parameter = 2.072 and scale parameter = 3.310. The gamma distribution is a two-parameter family of distributions. Changing the scale parameter merely changes the scale on the axes of the plotted function while the shape parameter

determines the shape of the distribution itself. The resulting times and cumulative distributions are displayed in Table IV. A random number was generated and the appropriate consultation time was determined based on the

Table IV
Consultation (Gamma) Distribution

Consult. time (mins.)	Cum. dist.	Consult. time (mins.)	Cum. dist.	Consult. time (mins.)	Cum. dist.
1.00	.0318	9.24	.7518	17.24	.9622
1.24	.0476	9.48	.7646	17.48	.9644
1.48	.0658	9.73	.7768	17.73	.9665
1.73	.0860	9.97	.7884	17.97	.9685
1.97	.1077	10.21	.7995	18.21	.9703
2.21	.1308	10.45	.8101	18.45	.9720
2.45	.1549	10.70	.8201	18.70	.9737
2.70	.1799	10.94	.8297	18.94	.9753
2.94	.2054	11.18	.8389	19.18	.9767
3.18	.2312	11.42	.8476	19.42	.9781
3.42	.2574	11.67	.8558	19.67	.9794
3.67	.2836	11.91	.8637	19.91	.9806
3.91	.3096	12.15	.8711	20.15	.9818
4.15	.3356	12.39	.8782	20.39	.9829
4.39	.3612	12.64	.8849	20.64	.9839
4.64	.3865	12.88	.8912	20.88	.9848
4.89	.4114	13.12	.8973	21.12	.9857
5.12	.4358	13.36	.9030	21.36	.9865
5.36	.4596	13.61	.9084	21.61	.9874
5.61	.4829	13.85	.9136	21.85	.9881
5.85	.5055	14.09	.9185	22.09	.9888
6.09	.5274	14.33	.9231	22.33	.9895
6.33	.5488	14.58	.9275	22.58	.9901
6.56	.5694	14.82	.9316	22.82	.9907
6.82	.5894	15.06	.9355	23.06	.9912
7.06	.6086	15.30	.9392	23.30	.9918
7.30	.6272	15.55	.9426	23.55	.9922
7.54	.6450	15.79	.9460	23.79	.9927
7.79	.6623	16.03	.9491	24.03	.9931
8.03	.6788	16.27	.9520	24.27	.9935
8.27	.6947	16.52	.9548	24.51	.9939
8.51	.7099	16.76	.9574	24.76	.9943
8.76	.7245	17.00	.9599	24.99	.9946
9.00	.7384				

associated cumulative distribution interval. Theoretically, the OB consultation times could vary from zero to infinity but to insure realistic operation the distribution was limited to values between one minute and twenty five minutes. This cut-off was based on the observed consultation times, none of which, were less than one minute or greater than twenty five minutes.

Simulation Model Output

The computer output format for each simulation run is shown in Fig. 9. Each alternative appointment system

APPOINTMENT SYSTEM X (RUN Y)

AVERAGE PATIENT WAITING TIME = xx.xx
AVERAGE LENGTH OF IDLE TIME = xx.xx
AVERAGE DOCTOR IDLE TIME = xx.xx
MEAN EARLY AT* OF PATIENT = xx.xx
MEAN CONSULTATION TIME = xx.xx
LENGTH OF CLINICAL SESSION = xx.xx
NUMBER OF WALK-IN PATIENTS = xx
MEAN NUMBER OF DOCTORS AVAIL = x.xx

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ.	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.			
10.			
15.			
20.			
25.			
30.			
35.			
40.			
45.			
50.			
55.			
60.			
OVER 60.			

* AT = Arrival Time

Fig. 9. Output Format For Simulation Model

was simulated over 25 clinic sessions. The particular session is designated by the run number. At the end of the 25 runs with each appointment system, a combined output was produced using the same format. In the combined output, the average figures are the average of the previous 25 run outputs and the individual waiting times are cumulative figures combining the results of the individual runs. All other entries are recorded as zeros in the combined output.

One set of the 25 individual run outputs is provided in Appendix D to demonstrate the variability involved from one run to the next, while using the same appointment system. Appendix E contains the cumulated output for all of the simulated appointment systems.

Validation of the Simulation Model

"A computer simulation model is considered valid if it produces results that are very close to the results that would be produced by the real-world system the computer model is suppose to represent" (Ref 3:164).

Several precautionary steps were taken during the construction of the computer simulation model to insure its validity. During the process of debugging the computer program, a number of the outputs from various sections of the program were printed out to allow individual analysis of each program section. Also to insure realistic clinic operation, each run output (as shown in Fig. 9) contains the mean value of three of the random variables (arrival

time, consultation time and number of doctors available) and the number of walk-in patients processed during the clinic session. These values were compared with the expected values of the distributions, from which the random variables were drawn, and were found to compare quite favorably. This assured that the computer mechanism for making random drawings from the stated distributions was operating properly. The final test of validation was the simulation of the appointment system currently being used and the comparison of those results to the data obtained during the observation periods. This comparison was quite satisfactory. During the observation periods the doctors had no idle time and the simulation model concurred, as can be seen by the results of appointment system 12 in Appendix E. The observations also revealed an average patient waiting time of from 55 to 65 minutes, after the appointment time, while the simulation model revealed a 70 minute waiting time per patient. The results of all the validation tests assured that the simulation model was acceptable for the purpose of this thesis.

Characteristics of the Simulation Program

The simulation computer program was developed and debugged in a period of approximately three weeks. The program was written for use on the IBM 360/40/G computer and some conversions may be required if a different computer is used. Each appointment system simulation of 25 runs takes from 8-10 minutes of computer time depending on system structure.

V. CONCLUSIONS AND RECOMMENDATIONS

The two main objectives that the patient arrival pattern must be designed to accomplish are reduction of waiting time to a minimum and preclusion of significant doctor idle time. Selection of the "best" appointment system centers around a balance between what an individual considers a "significant" amount of doctor idle time and what his particular goal is for reducing patient waiting time. Thus, the comparison of alternative appointment systems is highly dependent on subjective views.

The results of the 25 cumulated runs for each appointment system tested are given in Table V. Columns labeled average represent the average of the results of the 25 runs conducted on each system. It is evident that with each appointment system structure simulated an inverse relationship exists between patient waiting time and doctor idle time. Plotting the first five alternatives as in Fig. 10, one can see the resulting general trade-offs that exist for the OB clinic between patient waiting time and doctor idle time. This curve represents only one structural concept of appointment scheduling; however, by including the results of appointment systems 6 to 12 it is apparent that the type of appointment system structure has little affect on the shape of the waiting/idle time curve since the alternatives tend to cluster around the original curve.

Table V
Results of OB Clinic Simulations

Appt. system number	Average patient waiting time* (mins.)	Average doctor idle time (mins.)	Average length of idle time (mins.)
1	9.87	40.63	4.80
2	15.05	18.37	2.79
3	28.07	4.29	1.12
4	36.91	1.34	.40
5	38.62	.39	.35
6	16.51	22.49	3.23
7	28.87	2.82	1.01
8	44.18	.20	.42
9	12.89	35.23	4.40
10	26.90	2.23	.93
11	43.49	.17	.05
12	81.40	0.0	0.0

* Waiting times are based on patient's arrival time not on patient's appointment time. The mean arrival time is 11.14 minutes before the scheduled appointment time.

As stated previously, the present appointment system (number 12) is clearly unsatisfactory. All of the alternative systems have shorter average patient waiting times although some of the times resulted at the expense of incurring doctor idle time.

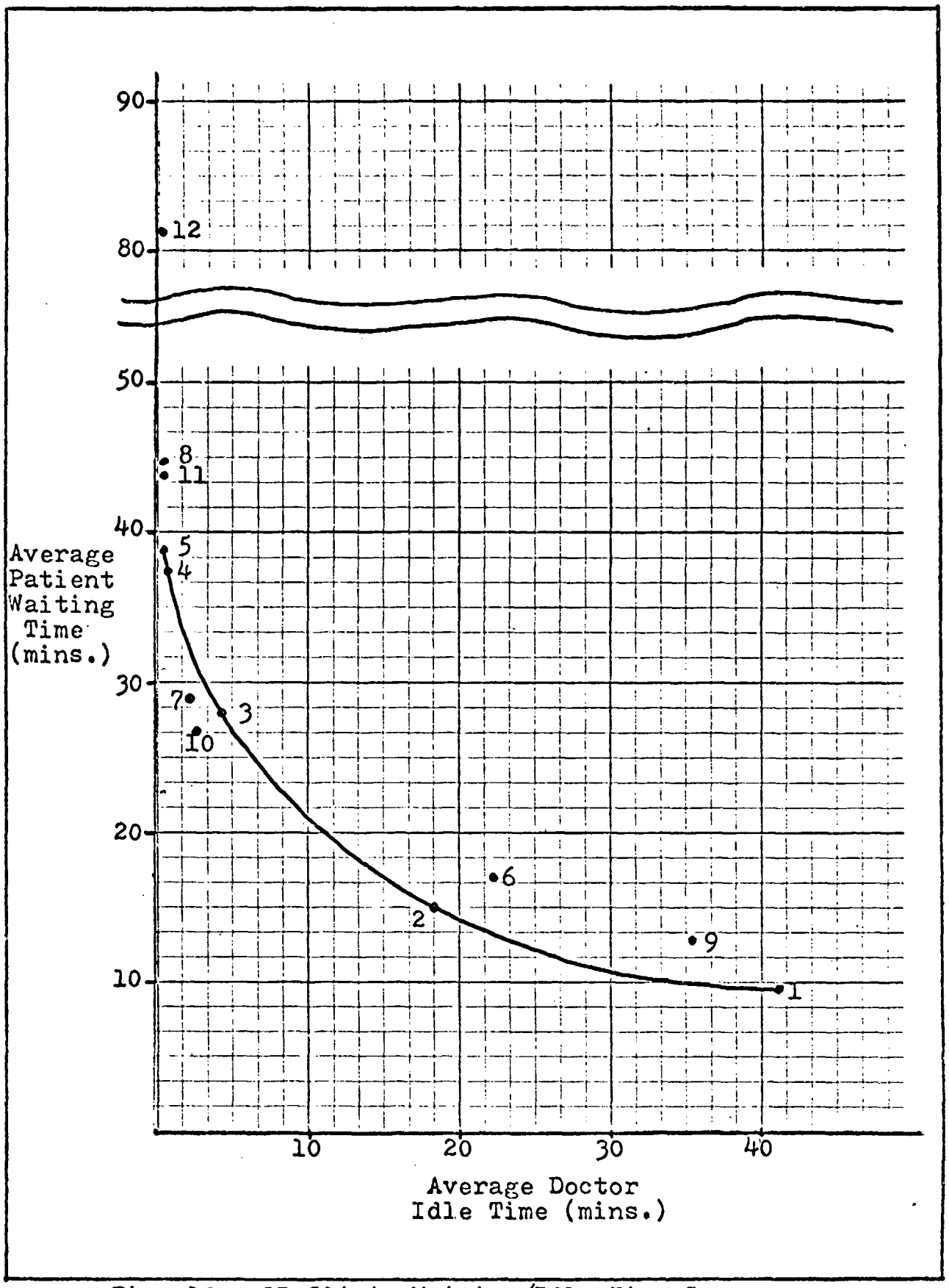

Fig. 10. OB Clinic Waiting/Idle Time Curve

Recommending an Appointment System

In searching for the "best" alternative appointment system of the twelve simulated, four characteristics of the appointment systems were analyzed:

(1) average patient waiting times

(2) average doctor idle times

(3) variation in the results of the individual runs

(4) individual waiting time distributions.

The first two characteristics were of primary concern with the third and fourth characteristics being used to select from those systems which were considered acceptable after analysis of waiting and idle times.

Appointment systems 3, 7 and 10 (see pages 29-30 for appointment system structure) seemed to be the most "realistic" from an average waiting and idle time viewpoint. All three had average idle times below 5 minutes and average waiting times below 30 minutes. The average waiting time figures were below 19 minutes with respect to the patient appointment times since the average patient waiting time in the simulation was calculated from the patients arrival time. These figures are all based on a clinic session of approximately 4 hours in length.

The third characteristic refers to how the averages were attained, i.e., were the results of all runs fairly consistent or did the individual run averages fluctuate high and low seldom approaching the cumulated average.

Table VI gives the range of the individual run averages for waiting time and idle time for appointment systems 3, 7 and 10. Appointment system 7 has the most stability

Table VI
Waiting/Idle Time Ranges

Appt. system	Waiting time range (mins.)	Idle time range (mins.)
3	7.52 to 62.89	0 to 30.51
7	13.88 to 60.84	0 to 16.97
10	6.69 to 68.49	0 to 23.45

from one run to the next as indicated by its waiting time and idle time ranges being less than the other two alternatives. This implies that appointment system 7 is less sensitive to the random variables that influence the OB clinic operations.

The fourth characteristic deals with how the individual patient's waiting times were distributed. The cumulative distributions for all appointment systems are included in Appendix E but Table VII shows the comparative figures for appointment systems 3, 7 and 10. By converting Millward's percentages from page 10 to waiting times based on patient arrival times, we find his "reasonable" guideline to be: 50% of the patients should be seen within twenty six minutes of their arrival times and 75% within forty one minutes; not more than 3% should have to wait more than seventy one

Table VII
Individual Waiting Time Distributions

Waiting time interval (mins.) upper limit	Cumulative percentages of patients		
	Appt. sys. 3	Appt. sys. 7	Appt. sys. 10
10	23.38	14.48	17.19
20	41.93	32.66	39.24
30	60.42	57.07	65.24
40	73.95	77.19	81.11
50	83.89	88.07	89.02
60	90.31	94.32	93.09
over 60	100.00	100.00	100.00

minutes. All three systems as seen in Table VII compare quite favorably with these guidelines. Recalling that the waiting time figures were arrived at by subtracting the arrival time (not the appointment time) from the consultation start time, those patients in the 0 to 10 minute interval were actually seen before their scheduled appointment times. Appointment system 3 is less satisfactory than systems 7 and 10 because 23.38% of the patients are receiving consultation prior to their appointment time and at the same time almost 10% are having to wait in excess of 60 minutes. Appointment systems 7 and 10 have quite similar distribution patterns with system 10 being slightly more favorable due to its greater cumulative percentages in the early time intervals.

The results of the analysis indicate that appointment system number 7 would "best" serve the needs of the OB clinic sessions. System 10 is a close second choice with system 3 a more distant third choice.

Implementation of Recommended Appointment System

Based on the preceeding recommendation, appointment system 7, which schedules 10 patients for the 1300 hours appointment and 5 patients at the beginning of each subsequent 10 minute period, should be implemented immediately. This appointment system is clearly superior to the one being used during the data collection period and there is very little chance that the immediate implementation of appointment system 7 will result in any complications worse than those already being encountered.

Due to the number of random variables affecting the OB clinic operation, the results of any appointment system selected will range greatly and waiting time or idle time problems will occur periodically during clinic sessions. Therefore, one must caution against judging the appointment system after only one or two days operation. Appointment system 7 will give the best over-all results but it is not immune from occasional unsatisfactory results.

If the results of the new appointment system are unsatisfactory or if further improvements are desired, a follow-up study should be conducted. This follow-up study should be undertaken after appointment system 7 has been

in use long enough (at least two months) to allow both patients and staff to adjust to the new system. The study should reexamine all the random variables to see if the actual implementation of the new system has caused a variation in any of the statistical distributions, i.e., has the doctor's consultation time with each patient increased because he no longer has a lengthy queue of patients waiting for consultation. If significant variations are noted, the simulation model should be adjusted and the appointment systems evaluated again. Also should it become desireable to investigate additional appointment systems, very little effort would be required to change the input data to the simulation model to enable evaluation of the new appointment systems.

Other General Operational Recommendations

During the data gathering sessions at the OB-GYN clinic, a number of ideas came to mind to improve the over-all operation. First, through interviews with patients it was apparent that their attitude is generally one of cooperation and understanding if they are kept informed. For example, if they know there is a shortage of doctors attending the clinic session and that the patients currently being seen had 1345 hours appointments even though it is now 1430 hours, they tend to accept the fact and patiently settle down for a long wait. At present, no apparent attempt is made to keep the patients informed unless the patient,

herself, asks the receptionist for information. This situation could be remedied in a number of ways ranging from having the receptionist announce the information in the waiting room every 15-20 minutes to an elaborate airport terminal type "chalk board" with such information displayed as number of doctors seeing patients, reason for shortage (if any) and appointment times of patients now being seen.

A second recommendation is that the receptionist not call patients from the waiting room to start the preliminary processing until the queue at the weight and blood pressure station is less than three. This will prevent patients from standing a significant amount of time in two waiting lines (receptionist and weight and blood pressure) before starting their consultations.

The third recommendation deals with the patient's next appointment. There seems to be no reason why appointments cannot be written out for each patient by someone on the clinic staff prior to the day of the clinic. The patient's next appointment could be placed in her medical record folder and presented to her when she starts processing rather than letting the queue build as the receptionist records each new appointment in the log and on the patient's appointment slip.

Finally, some action should be taken to insure all necessary records are on hand in the clinic prior to the day of the clinic session. This recommendation pertains

to the GYN clinic primarily. The main reason for records not being transferred from the records center to the clinic is that the patient failed to provide her husbands social security number when making the appointment. Since all records are filed under social security numbers, the records center will refuse to process the transfer request without that information. A solution here might be to refuse to make the appointment until the individual provides the necessary information or to take some action to find out the information such as phoning the patient before her appointment date.

Areas for Further Study

The WPAFB Medical Center is virtually an unlimited resource for topics acceptable for thesis research. Appointment system problems of one type or another exist in practically all clinics. The emergency room waiting area is usually fully occupied indicating either a shortage of medical personnel or misuse of the facility by the patient or both. Another area for study is the scheduling of operating room facilities and their operation. The pharmacy faces problems of queues and inventories. Cost/benefit studies could be performed on the advantages/disadvantages of the use of manditory medicare versus increasing the clinic facilities and manning. These are but a few of the many areas that lend themselves to further studies.

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APPENDIX A

CHI SQUARE GOODNESS OF FIT TEST

(ARRIVAL PATTERN)

Chi Square Test

Classes*	Observed Freq's (f_o)	Normal Prob.	Expected Freq's (f_e)	$\frac{(f_o-f_e)^2}{f_e}$
less than -20.4	1	.0028	0	.64
-20.4 to -14.8	2	.0096	1	
-14.8 to -9.2	1	.0277	4	
-9.2 to -3.6	7	.0629	9	
-3.6 to +2.0	13	.1139	17	.94
+2.0 to +7.6	28	.1644	26	.15
+7.6 to +13.2	31	.1893	28	.32
+13.2 to +18.8	39	.1708	27	5.33
+18.8 to +24.4	16	.1286	19	.47
+24.4 to +30.0	7	.0755	11	1.54
+30.0 to +35.6	2	.0354	5	1.12
+35.6 to +41.2	0	.0132	2	
+41.2 to +46.8	2	.0040	1	
+46.8 to +52.4	0	.0009	0	
over +52.4	1	.0002	0	
	150			10.51

Computed Chi Square value = 10.51

Since 10.51 is less than 11.1, the Chi Square value with 8-2-1 or 5 degrees of freedom at the .05 level of significance, the arrival pattern is assumed to be normally distributed with mean = 11.14 and variance = 137.13.

* Positive values represent minutes arrived before appointment time. Negative values represent minutes arrived after appointment time.

APPENDIX B

KOLMOGOROV-SMIRNOV GOODNESS OF FIT TEST

(CONSULTATION TIMES)

The following computer program was used to conduct a Kolmogorov-Smirnov goodness of fit test (Ref 2:436) on the data obtained during the GYN and OB consultation periods. The main program and gamma distribution test subroutine are contained here for your information. The program has the capability to test for normality as well and contains a histogram subroutine to plot the data points. The program was written by William B. Askren and Thaddeus L. Regulinski and was extracted from Mathematical Modeling of Human Performance Errors for Reliability Analysis of Systems, AMRL-TR-68-93, dated January 1969.

```
C  PD  MAIN
      DIMENSION X(1000),FMT(20),HDG(20)
      READ(5,1) NSETS,INORM,IGAM
    1 FORMAT(3I5)
      READ(5,2) FMT
      DO 100 JJ=1,NSETS
      READ(5,2) HDG
      READ(5,1) NPTS
      READ(5,FMT) (X(I),I=1,NPTS)
    2 FORMAT(20A4)
      NDF=NPTS-1
      CALL HIST(X,NPTS,NDF,10,3)
      NL=NDF
   10 INT=1
      DO 15 L=1,NL
      IF(X(L+1).GE.X(L)) GO TO 15
      TEMP=X(L+1)
      X(L+1)=X(L)
      X(L)=TEMP
      INT=L
   15 CONTINUE
      IF(INT.EQ.1) GO TO 16
      NL=INT-1
      GO TO 10
   16 IF(INORM.NE.1) GO TO 20
      CALL NORMAL(X,NPTS,HDG)
   20 IF(IGAM.NE.1) GO TO 100
      CALL GAMA(X,NPTS,HDG,SMIRK)
  100 CONTINUE
      STOP
      END
```

Kolmogorov-Smirnov(K-S) Test Subroutine

```
      SUBROUTINE GAMA(T,N,HDG,SMIRK)
C   GAMMA DISTRIBUTION
      DIMENSION T(1),HDG(20)
   32 FORMAT(T50,'GAMMA DISTRIBUTION',////,30X,5HSHAPE,
     10X,5HSCALE,111X,4HMEAN,7X,8HVARIANCE,11X,4HMODE,
     /,20X,5F15.4//)
   33 FORMAT(10X,4F15.4)
   46 FORMAT(T20,'LARGEST DIFFERENCE IS',F8.4)
   47 FORMAT(T20,'MAXIMUM K-S STATISTIC ALLOWABLE IS',F8.4)
   48 FORMAT(T20,'K-S TEST   ***FAILED***')
   49 FORMAT(T20,'K-S TEST   ***PASSED***')
      XN=N
      IF(N.GE.35) SMIRK=1.63/SQRT(XN)
      WRITE(6,20) HDG
   20 FORMAT(1H1,25X,20A4)
      BIG=0.
      SQ=0.
      TOT=0.
      DO 50 I=1,N
      TOT=TOT+T(I)
   50 SQ=SQ+T(I)*T(I)
      S=(SQ-TOT*TOT/XN)/(XN-1.)
      AVT=TOT/XN
      BETA=S/AVT
      ALPHA=AVT/BETA
      XMU=ALPHA*BETA
      VAR=XMU*BETA
      XMO=XMU-BETA
      WRITE(6,32) ALPHA,BETA,XMU,VAR,XMO
      DEM=GAMMA(ALPHA)*BETA**ALPHA
      ZN=0.
      DO 70 I=1,N
      ZN=ZN+1.
      FOX=ZN/XN
      IF(I-1)65,65,66
   66 J=I-1
      IF(T(I)-T(J))67,67,68
   68 A=T(J)
      X=T(I)
      GO TO 69
   65 X=T(I)
      FTX=0.
   84 A=0.1*T(1)
   69 K=0
      L=0
      B=X
      EPS=.05/XN
      MIT=20
      TERM=0.
      DELTX=(B-A)/4.
      DEL2=DELTX+DELTX
      PSUM=0.
```

```
      Y=A
      TERM=Y**(ALPHA-1.)/EXP(Y/BETA)
      QSUM=TERM
      Y=B
      TERM=Y**(ALPHA-1.)/EXP(Y/BETA)
      QSUM=QSUM+TERM
      ESUM=0.
      Y=A
    1 Y=Y+DEL2
      TERM=Y**(ALPHA-1.)/EXP(Y/BETA)
      ESUM=ESUM+TERM
      IF(Y-B+DEL2+DELTX)1,2,2
    2 ODSUM=0.
      Y=A-DELTX
    3 Y=Y+DEL2
      TERM=Y**(ALPHA-1.)/EXP(Y/BETA)
      ODSUM=ODSUM+TERM
      IF(Y+DEL2-B)3,4,4
    4 SUM=(QSUM+ESUM+ESUM+4.*ODSUM)*DELTX/3.
      K=K+1
      IF(ABS((SUM-PSUM)/SUM)-EPS)6,5,5
    5 IF(K-MIT)8,9,9
    8 DEL2=DELTX
      DELTX=0.5*DELTX
      PSUM=SUM
      ESUM=ESUM+ODSUM
      GO TO 2
    9 MIT=MIT+10
      FPS=FPS*10.
      L=L+1
      IF(L-5)8,6,6
    6 FTX=FTX+SUM/DEM
   67 DIFF=ABS(FOX-FTX)
      IF(BIG-DIFF)80,70,70
   80 BIG=DIFF
   70 WRITE(6,33) X,FOX,FTX,DIFF
      WRITE(6,46) BIG
      WRITE(6,47) SMIRK
      IF(BIG-SMIRK)86,86,85
   85 WRITE(6,48)
      GO TO 99
   86 WRITE(6,49)
   99 CONTINUE
      RETURN
      END
```

Final Results of K-S Test (Gamma Distribution)

GYN Consultations:

Shape parameter = 5.2920
Scale parameter = 4.0816
Mean = 21.6
Variance = 88.1632
Mode = 17.5183

Largest difference is 0.0921
Maximum K-S statistic allowable is 0.2305
K-S TEST ***PASSED***

OB Consultations:

Shape parameter = 2.0724
Scale parameter = 3.3101
Mean = 6.86
Variance = 22.7075
Mode = 3.5499

Largest difference is 0.1581
Maximum K-S statistic allowable is 0.1630
K-S TEST ***PASSED***

APPENDIX C

COMPUTER SIMULATION FLOW DIAGRAM AND PROGRAM

Listing of Program Variables

ADW - Doctor idle time.

ALPHA - Shape of service(consultation) time gamma distribution.

AM - Mean of normally distributed arrival times.

AN - Number of patients attending clinic session (includes both appointment patients and walk-ins).

APW - Patient waiting time.

AT(NP,I)- Arrival/appointment time array where column 1(I=1) contains the arrival time of patient number NP and the associated appointment time is contained in column 2(I=2).

BETA - Scale of service(consultation) time gamma distribution.

CDDA - Cumulative discrete distribution of number of doctors available for clinic sessions.

DAT - Doctor availability time.

DN - Number of occurances of ADW.

EX - Mean inter-arrival time of walk-in patients.

KK - Number of entries in TDA and NDA arrays.

N - Number of appointment patients simulated.

NDA - Number of doctors available at TDA.

NP - Number of patient being simulated.

NSETS - Number of appointment systems to be simulated.

PWT - Array to record each patients waiting time.

SER - Length of service(consultation) time.

STDA - Standard deviation of normally distributed arrival times.

TDA - Time at which the number of doctors available is adjusted.

WT - Walk-in times.

Explanation of Program Subroutines

GAMCD - Computes a discrete cumulative distribution to approximate a specified gamma distribution. This discrete distribution is used to approximate random drawings from the gamma consultation time distribution.

GAUSS - Performs a random draw from a normal distribution with specified mean and standard deviation. This is an IBM 360 internal subroutine.

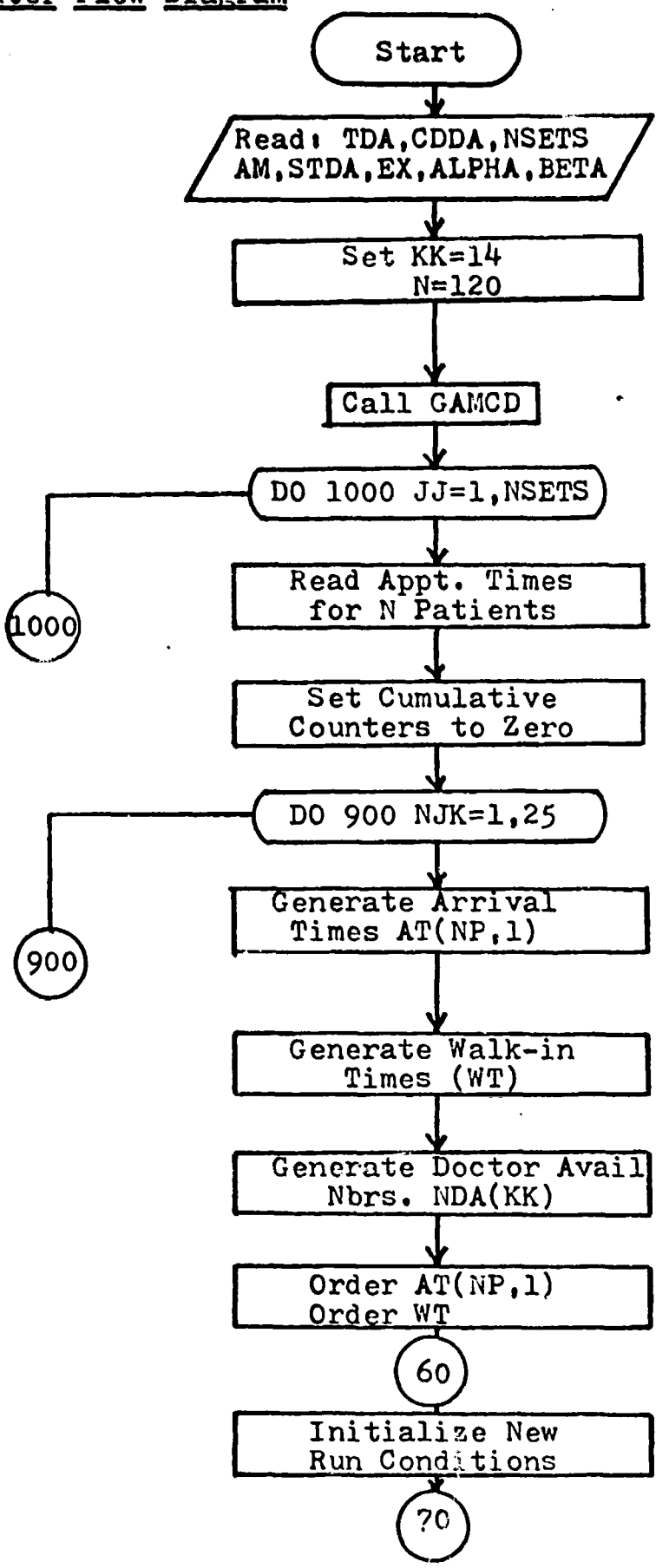
ORDER - Orders(earliest time first) a one column array.

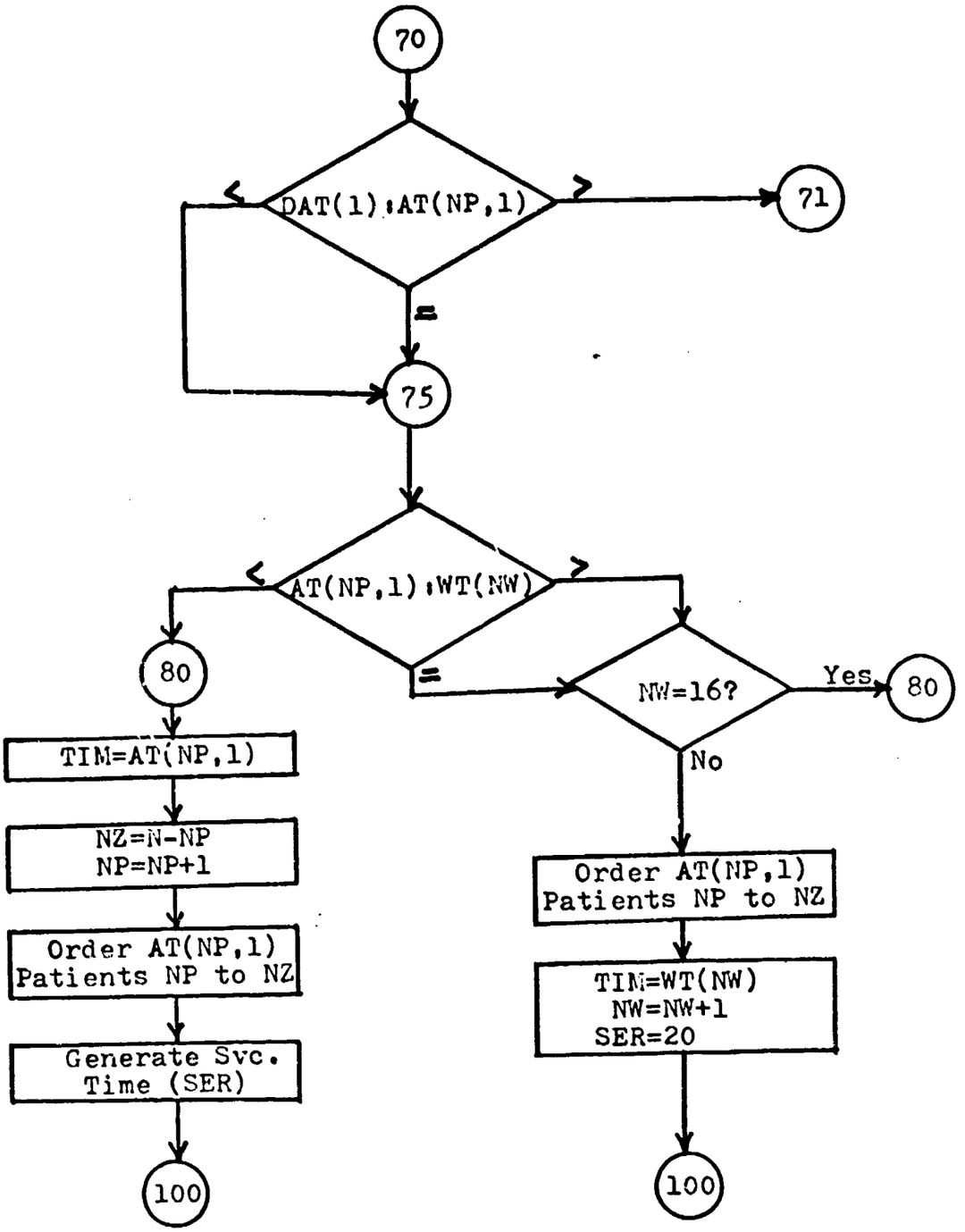
ORD2 - Orders(earliest time first) a two column array on the column that is specified. Also permits ordering a variable number of the rows of the array.

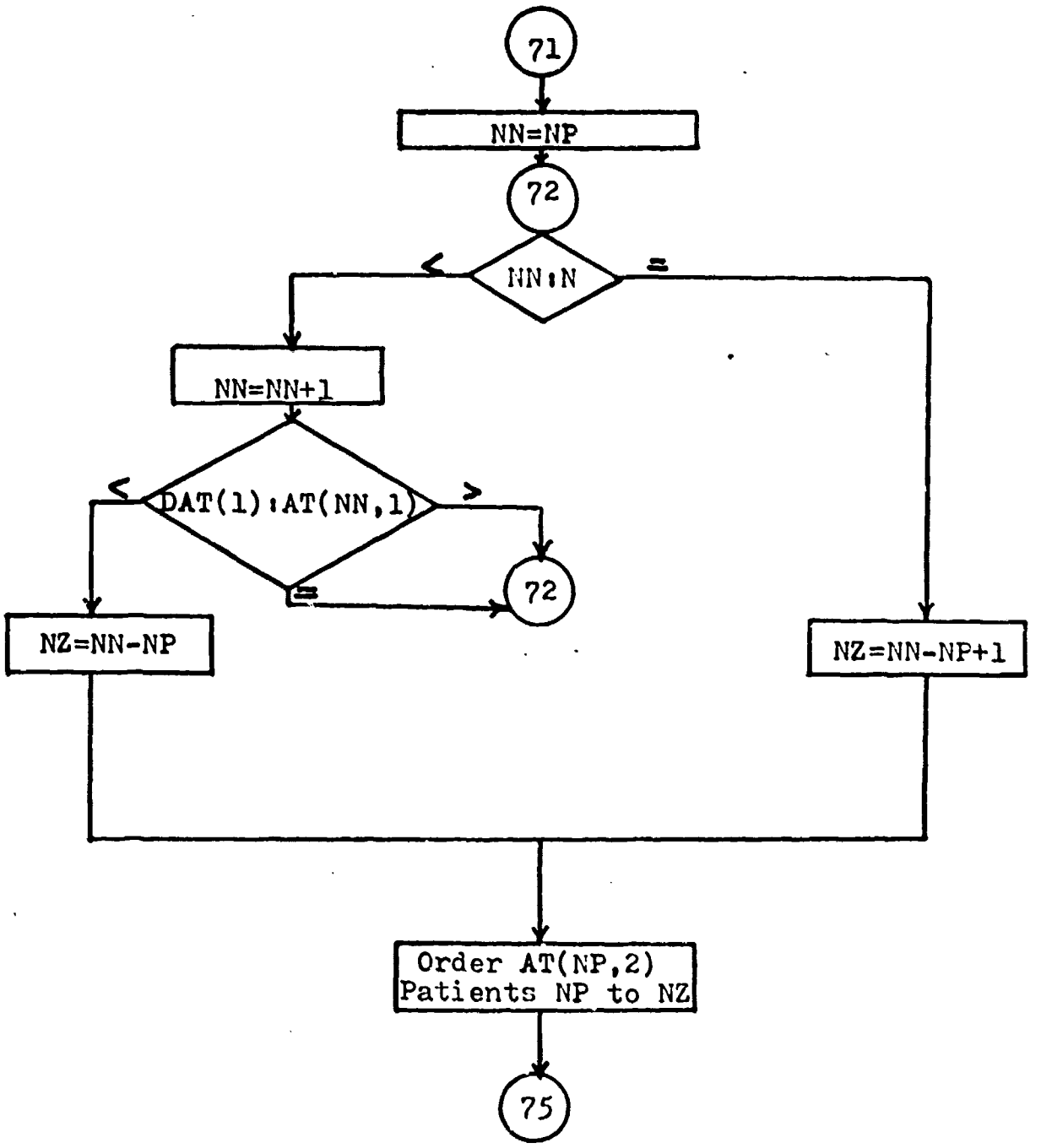
RANDU - IBM 360 internal subroutine to generate random numbers.

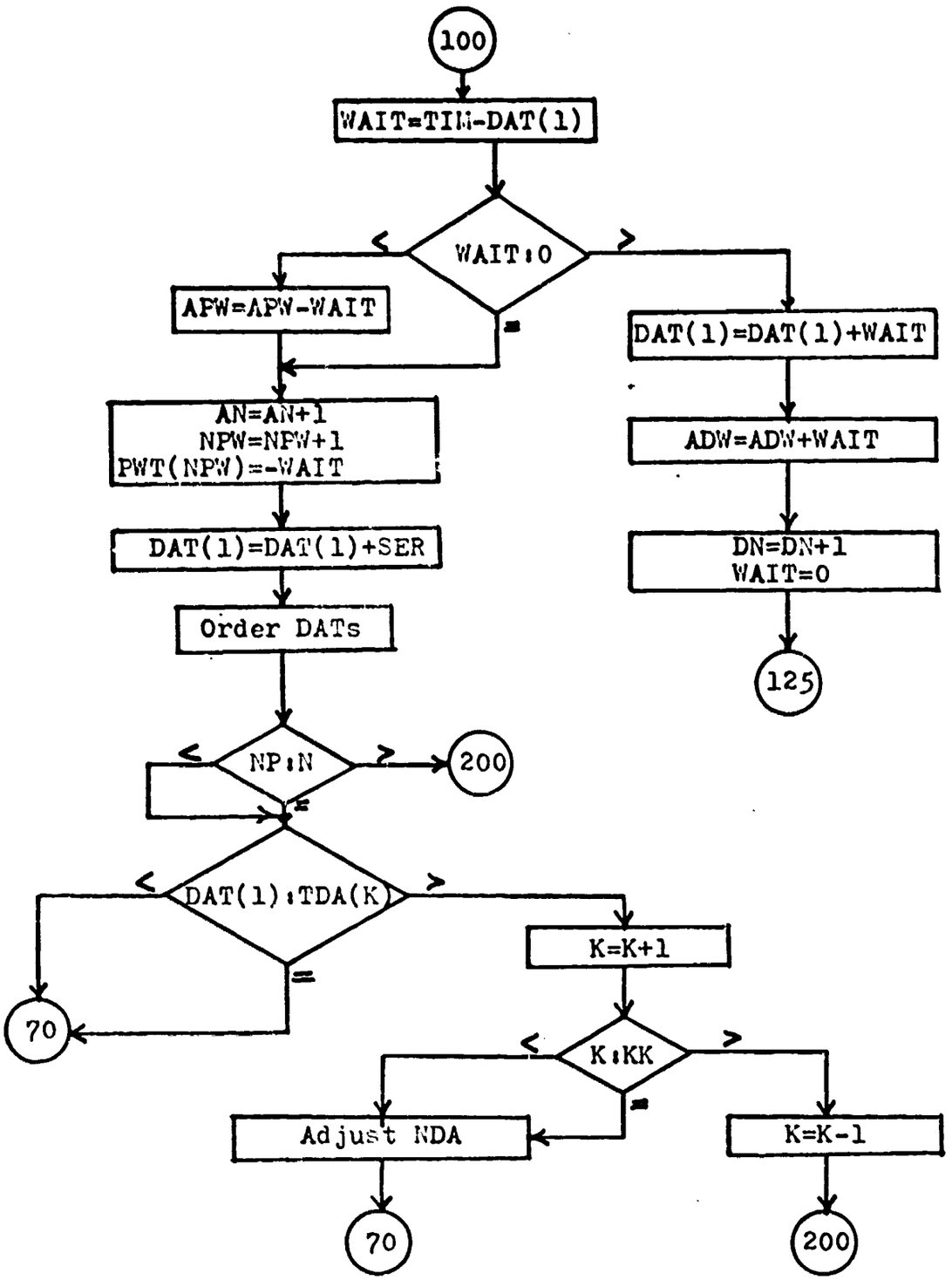
WRIT - Provides the instructions for the simulation model computer output.

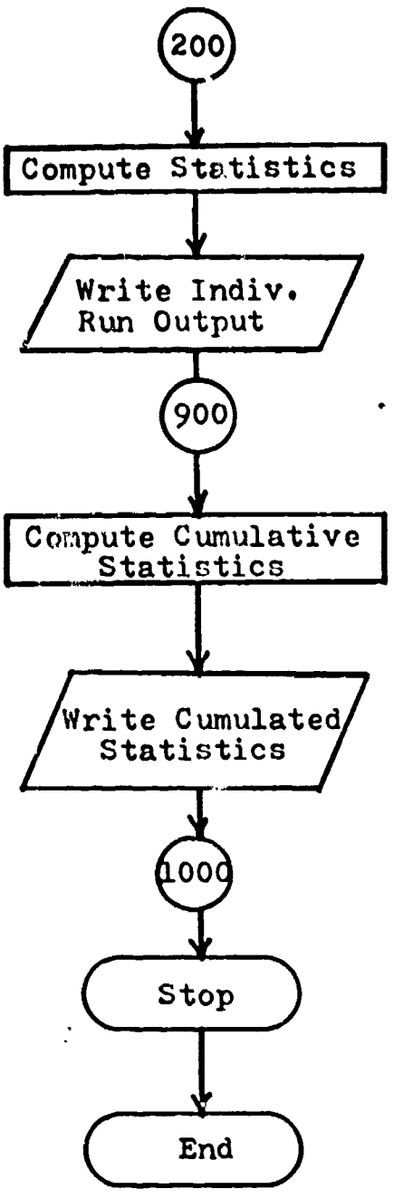
Computer Flow Diagram




70
DAT(1):AT(NP,1)
<
=
>
71
75
AT(NP,1):WT(NW)
<
=
>
80
TIM=AT(NP,1)
NZ=N-NP
NP=NP+1
Order AT(NP,1)
Patients NP to NZ
Generate Svc.
Time (SER)
100
NW=16?
Yes
80
No
Order AT(NP,1)
Patients NP to NZ
TIM=WT(NW)
NW=NW+1
SER=20
100


71
NN=NP
72
NN:N
<
=
NN=NN+1
DAT(1):AT(NN,1)
<
>
=
72
NZ=NN-NP
NZ=NN-NP+1
Order AT(NP,2)
Patients NP to NZ
75


100
WAIT=TIM-DAT(1)
WAIT:0
<
=
>
APW=APW-WAIT
DAT(1)=DAT(1)+WAIT
AN=AN+1
NPW=NPW+1
PWT(NPW)=-WAIT
ADW=ADW+WAIT
DAT(1)=DAT(1)+SER
DN=DN+1
WAIT=0
Order DATs
125
NP:N
200
DAT(1):TDA(K)
K=K+1
70
K:KK
Adjust NDA
K=K-1
70
200


200
Compute Statistics
Write Indiv. Run Output
900
Compute Cumulative Statistics
Write Cumulated Statistics
1000
Stop
End

```
C AT = ARRIVAL TIMES
C AM = MEAN OF NORMALLY DISTRIBUTED AT
C STDA = STANDARD DEV OF AT
C WT = WALK-IN TIMES
C EX = MEAN INTER ARRIVAL TIME OF WALK-IN PATIENTS
C DAT = DOCTOR AVAILABILITY TIME
C NDA = NUMBER OF DOCTORS AVAILABLE
C TDA = TIME DOCTORS AVAILABLE
C ALPHA = SHAPE OF GAMMA DISTRIBUTION
C BETA = SCALE OF GAMMA DISTRIBUTION
      DIMENSION AT(150,2),WT(15),DAT(6),NDA(14),TDA(14)
     *,CDDA(7),G(200),CD(200),PWT(4000)
      COMMON AT
      DATA TDA/65.,95.,125.,155.,185.,215.,245.,275.,305.,
     *335.,365.,395.,425.,455./
      DATA CDDA/0.,.02,.12,.43,.74,.98,1.0/
C READ PARAMETERS OF DISTRIBUTIONS AND DATA
      KK=14
      N=120
      XN=N
      READ(5,1) NSETS
      READ(5,2) AM,STDA,EX,ALPHA,BETA
    1 FORMAT(I5)
    2 FORMAT(5F10.0)
C GENERATE GAMMA DISTR
      NN=100
      CALL GAMCD(G,CD,ALPHA,BETA,NN,1.,25.)
      IX=531
C READ APPOINTMENT TIMES
      DO 1000 JJ=1,NSETS
      READ(5,3) (AT(I,2),I=1,N)
    3 FORMAT(20F4.0)
      NPW=0
      AVV=0.
      CTM=0.
      CSL=0.
      AAPW=0.
      AADW=0.
      AAVD=0.
      DO 900 NJK=1,25
C GENERATE N ARRIVAL TIMES  NORMAL DISTR
      DO 30 J=1,N
   25 CALL GAUSS(IX,STDA,AM,V)
      IF(V.LT.-20..OR.V.GT.70.) GO TO 25
      AVV=AVV+V
   30 AT(J,1)=AT(J,2)-V
      AVV=AVV/XN
C GENERATE 15 WALK-IN ARRIVAL TIMES    EXPONENTIAL DISTR
      TEMP=60.
      DO 40 J=1,15
      CALL RANDU(IX,IY,YFL)
      IX=IY
      WT(J)=-EX*ALOG(YFL)
      WT(J)=TEMP+WT(J)
```

```
   40  TEMP=WT(J)
C GENERATE KK DOC AVAILABLE NBRS (EVERY 30 MIN)
       DO 50 J=1,KK
       CALL RANDU(IX,IY,YFL)
       IX=IY
       DO 45 L=2,7
       IF(.NOT.(YFL.GE.CDDA(L-1).AND.YFL.LT.CDDA(L))) GO TO 45
       NDA(J)=L-1
       GO TO 50
   45  CONTINUE
   50  CONTINUE
C ORDER ARRIVAL TIMES
       CALL ORD2(1,N,1)
       CALL ORDER(WT,15)
C INIALIZE DAT
       DO 60 L=1,6
   60  DAT(L)=65.
       M=NDA(1)
       NP=1
       NW=1
       NTDA=M
       AN=0.
       DN=0.
       APW=0.
       ADW=0.
       K=1
C COMPARE DOCTOR AVAIL TIME TO PATIENT AT
       MM=20
   70  IF(DAT(1).LE.AT(NP,1)) GO TO 75
   71  NN=NP
   72  IF(NN.EQ.N) GO TO 73
       NN=NN+1
       IF(DAT(1).GE.AT(NN,1)) GO TO 72
       NZ=NN-NP
       GO TO 74
   73  NZ=NN-NP+1
   74  CALL ORD2(NP,NZ,2)
   75  IF(AT(NP,1).LT.WT(NW)) GO TO 80
       IF(NW.GT.15) GO TO 80
       CALL ORD2(NP,NZ,1)
       TIM=WT(NW)
       NW=NW+1
       SER=20.
        GO TO 100
C REORDER ARRIVAL TIMES
   80  TIM=AT(NP,1)
           NZ=N-NP
       NP=NP+1
       CALL ORD2(NP,NZ,1)
C GENERATE SERVICE TIME
       CALL RANDU(IX,IY,YFL)
       IX=IY
       IF(YFL.GT.CD(1)) GO TO 85
       SER=G(1)
```

```
      GO TO 100
   85 IF(YFL.LT.CD(100)) GO TO 90
      SER=G(100)
      GO TO 100
   90 DO 95 L=2,100
      IF(.NOT.(YFL.GE.CD(L-1).AND.YFL.LT.CD(L))) GO TO 95
      SER=G(L)
      CTM=CTM+SER
      GO TO 100
   95 CONTINUE
C CALCULATE WAITING OR IDLE TIME
  100 WAIT=TIM-DAT(1)
      IF(WAIT)120,125,110
  110 ADW=ADW+WAIT
      DAT(1)=DAT(1)+WAIT
      DN=DN+1.
      WAIT=0.
      GO TO 125
C RECORD PATIENT WAITING TIME
  120 APW=APW-WAIT
  125 AN=AN+1.
      NPW=NPW+1
      PWT(NPW)=-WAIT
C ADD SER TIME TO DOC AVAIL TIME
  130 DAT(1)=DAT(1)+SER
      CSL=DAT(1)-60.
      CALL ORDER(DAT,M)
      IF(NP.GT.N) GO TO 200
      IF(DAT(1).LE.TDA(K+1)) GO TO 70
      K=K+1
      IF(K.LT.KK)GO TO 135
      K=K-1
      GO TO 200
  135 J=M
      M=NDA(K)
      NTDA=NTDA+M
      IF(J-M)140,70,150
  140 L=J+1
      DO 145 I=L,M
  145 DAT(I)=TDA(K)
      GO TO 70
  150 L=J-M
      DO 155 I=1,M
  155 DAT(I)=DAT(I+L)
      GO TO 70
C COMPUTE AVG WAITING AND IDLE TIMES
  200 APW=APW/AN
      XNTDA=FLOAT(NTDA)/FLOAT(K)
      AVD=ADW/XNTDA
      IF(DN.EQ.0.) GO TO 210
      ADW=ADW/DN
      GO TO 220
  210 ADW=0.
```

```
      AVD=0.
  220 CONTINUE
      WRITE(6,6)JJ,NJK
    6 FORMAT(1H1,10X,'APPOINTMENT SYSTEM',I3,' (RUN',I3,')',//)
      MM=AN
      M=NPW-MM+1
      CTM=CTM/XN
      NW=NW-1
      CALL WRIT(APW,ADW,AVD,PWT(M),MM,AVV,CTM,CSL,NW,XNTDA)
      AAPW=AAPW+APW
      AADW=AADW+ADW
      AAVD=AAVD+AVD
  900 CONTINUE
      ANN=NJK
      AAPW=AAPW/ANN
      AADW=AADW/ANN
      AAVD=AAVD/ANN
      WRITE(6,7) JJ,NJK
    7 FORMAT(1H1,10X,'APPOINTMENT SYSTEM',I3,'(ALL',I3,
     *' RUNS COMBINED)',//)
      AVV=0.
      CTM=0.
      CSL=0.
      NW=0
      XNTDA=0
      CALL WRIT(AAPW,AADW,AAVD,PWT,NPW,AVV,CTM,CSL,NW,XNTDA)
 1000 CONTINUE
      STOP
      END
```

```
      SUBROUTINE WRIT(APW,ADW,AVD,X,N,AVV,CTM,CSL,NW,XNIDA)
      DIMENSION X(1),NCT(13),ULIM(13)
      DATA ULIM/5.,10.,15.,20.,25.,30.,35.,40.,45.,50.,55.,60./
      WRITE(6,6) APW,ADW,AVD,AVV,CTM,CSL,NW,XNIDA
    6 FORMAT(10X,'AVERAGE PATIENT WAITING TIME =',F7.2,' MIN',/,
     1       10X,'AVERAGE LENGTH OF IDLE TIME  =',F7.2,' MIN',/,
     2       10X,'AVERAGE DOCTOR IDLE TIME     =',F7.2,' MIN',/,
     310X,'MEAN EARLY AT OF PATIENT     =',F7.2,/,
     410X,'MEAN CONSULTATION TIME       =',F7.2,/,
     510X,'LENGTH OF CLINICAL SESSION   =',F7.2,/,
     610X,'NUMBER OF WALK-IN PATIENTS   =',  I7,/,
     710X,'MEAN NUMBER OF DOCTORS AVAIL =',F7.2,//)
      WRITE(6,7)
    7 FORMAT(13X,'INDIVIDUAL WAITING TIMES',//,
     121X,'UPPER  OBS.  PERCENT   CUMULATIVE',/,
     221X,'LIMIT  FREQ  OF TOTAL  PERCENTAGE')
C
      DO 15 J=1,13
   15 NCT(J)=0
      CPC=0.
      M=0
   20 M=M+1
      IF(M.GT.N) GO TO 60
      IF(X(M).GT.5.) GO TO 30
      NCT(1)=NCT(1)+1
      GO TO 20
C
   30 IF(X(M).LE.60.) GO TO 40
      NCT(13)=NCT(13)+1
      GO TO 20
C
   40 DO 50 J=2,12
      IF(.NOT.(X(M).GT.ULIM(J-1).AND.X(M).LE.ULIM(J))) GO TO 50
      NCT(J)=NCT(J)+1
      GO TO 20
   50 CONTINUE
C
   60 XN=N
      DO 70 J=1,12
      PCT=FLOAT(NCT(J))*100./XN
      CPC=CPC+PCT
   70 WRITE(6,8) ULIM(J),NCT(J),PCT,CPC
    8 FORMAT(21X,F4.0,I7,F9.2,F11.2)
C
      PCT=FLOAT(NCT(13))*100./XN
      CPC=100.
      WRITE(6,9) ULIM(12),NCT(13),PCT,CPC
    9 FORMAT(17X,'OVER',F4.0,I7,F9.2,F11.2)
      RETURN
      END
```

```
      SUBROUTINE ORD2(M,N,I)
C M = STARTING INDEX
C N = NUMBER TO ORDER
C I = SECOND SUBSCRIPT TO ORDER ON
      DIMENSION X(150,2)
      COMMON X
      IF(N.LE.1) RETURN
      MM=N+M-2
   10 INT=M
      DO 20 L=M,MM
      IF(X(L+1,I).GE.X(L,I)) GO TO 20
      DO 15 J=1,2
      TP1=X(L+1,J)
      X(L+1,J)=X(L,J)
   15 X(L,J)=TP1
      INT=L
   20 CONTINUE
      IF(INT.EQ.M) RETURN
      MM=INT-1
      GO TO 10
      END
```

```
      SUBROUTINE ORDER(X,N)
      DIMENSION X(1)
      IF(N.LE.1) RETURN
      M=N-1
   10 INT=1
      DO 20 L=1,M
      IF(X(L+1).GE.X(L)) GO TO 20
      TEMP=X(L+1)
      X(L+1)=X(L)
      X(L)=TEMP
      INT=L
   20 CONTINUE
      IF(INT.EQ.1) RETURN
      M=INT-1
      GO TO 10
      END
```

```
      SUBROUTINE GAMCD(X,CD,ALPHA,BETA,N,BLIM,ULIM)
C GENERATES GAMMA CUMULATIVE DISTRIBUTION
      DIMENSION X(1),CD(1)
      XN=N
      OEM=GAMMA(ALPHA)*BETA**ALPHA
      DELTX=(ULIM-BLIM)/(XN-1.)
      X(1)=BLIM
      DO 50 J=2,N
   50 X(J)=X(J-1)+DELTX
C
      DO 70 I=1,N
      IF(I-1)65,65,66
   66 J=I-1
      IF(X(I).LE.X(J)) GO TO 70
   68 A=X(J)
      T=X(I)
      GO TO 69
   65 T=X(I)
      FTX=0.
   84 A=0.1*X(1)
   69 K=0
      L=0
      B=T
      EPS=.05/XN
      MIT=20
      TERM=0.
      DELTX=(B-A)/4.
      DEL2=DELTX+DELTX
      PSUM=0.
      Y=A
      TERM=Y**(ALPHA-1.)/EXP(Y/BETA)
      QSUM=TERM
      Y=B
      TERM=Y**(ALPHA-1.)/EXP(Y/BETA)
      QSUM=QSUM+TERM
      ESUM=0.
      Y=A
    1 Y=Y+DEL2
      TERM=Y**(ALPHA-1.)/EXP(Y/BETA)
      ESUM=ESUM+TERM
      IF(Y-B+DEL2+DELTX)1,2,2
    2 ODSUM=0.
      Y=A-DELTX
    3 Y=Y+DEL2
      TERM=Y**(ALPHA-1.)/EXP(Y/BETA)
      ODSUM=ODSUM+TERM
      IF(Y+DEL2-B)3,4,4
    4 SUM=(QSUM+ESUM+ESUM+4.*ODSUM)*DELTX/3.
      K=K+1
      IF(ABS((SUM-PSUM)/SUM)-EPS)6,5,5
    5 IF(K-MIT)8,9,9
    8 DEL2=DELTX
      DELTX=0.5*DELTX
      PSUM=SUM
```

```
      ESUM=ESUM+ODSUM
      GO TO 2
    9 MIT=MIT+10
      FPS=FPS*10.
      L=L+1
      IF(L-5)8,6,6
    6 FTX=FTX+SUM/DEM
      CO(I)=FTX
   70 CONTINUE
      RETURN
      END
```

APPENDIX D

SAMPLE OF INDIVIDUAL RUN OUTPUTS
(Appointment System 7 Only)

APPOINTMENT SYSTEM 7 (RUN 1)

AVERAGE PATIENT WAITING TIME	=	18.67 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.0 MIN
AVERAGE DOCTOR IDLE TIME	=	0.0 MIN
MEAN EARLY AT OF PATIENT	=	11.41
MEAN CONSULTATION TIME	=	6.74
LENGTH OF CLINICAL SESSION	=	245.51
NUMBER OF WALK-IN PATIENTS	=	7
MEAN NUMBER OF DOCTORS AVAIL	=	4.25

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	7	5.51	5.51
10.	12	9.45	14.96
15.	21	16.54	31.50
20.	41	32.28	63.78
25.	19	14.96	78.74
30.	15	11.81	90.55
35.	5	3.94	94.49
40.	5	3.94	98.43
45.	1	0.79	99.21
50.	1	0.79	100.00
55.	0	0.0	100.00
60.	0	0.0	100.00
OVER 60.	0	0.0	100.00

APPOINTMENT SYSTEM 7 (RUN 2)

AVERAGE PATIENT WAITING TIME	= 18.58 MIN
AVERAGE LENGTH OF IDLE TIME	= 5.79 MIN
AVERAGE DOCTOR IDLE TIME	= 16.97 MIN
MEAN EARLY AT OF PATIENT	= 13.80
MEAN CONSULTATION TIME	= 6.51
LENGTH OF CLINICAL SESSION	= 232.99
NUMBER OF WALK-IN PATIENTS	= 1
MEAN NUMBER OF DOCTORS AVAIL	= 3.75

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	25	20.66	20.66
10.	12	9.92	30.58
15.	14	11.57	42.15
20.	21	17.36	59.50
25.	9	7.44	66.94
30.	9	7.44	74.38
35.	16	13.22	87.60
40.	11	9.09	96.69
45.	0	0.0	96.69
50.	2	1.65	98.35
55.	1	0.83	99.17
60.	1	0.83	100.00
OVER 60.	0	0.0	100.00

APPOINTMENT SYSTEM 7 (RUN 3)

AVERAGE PATIENT WAITING TIME	= 30.12 MIN
AVERAGE LENGTH OF IDLE TIME	= 0.0 MIN
AVERAGE DOCTOR IDLE TIME	= 0.0 MIN
MEAN EARLY AT OF PATIENT	= 11.94
MEAN CONSULTATION TIME	= 6.75
LENGTH OF CLINICAL SESSION	= 239.51
NUMBER OF WALK-IN PATIENTS	= 3
MEAN NUMBER OF DOCTORS AVAIL	= 3.63

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	0	0.0	0.0
10.	0	0.0	0.0
15.	7	5.69	5.69
20.	16	13.01	18.70
25.	20	16.26	34.96
30.	24	19.51	54.47
35.	20	16.26	70.73
40.	17	13.82	84.55
45.	9	7.32	91.87
50.	3	2.44	94.31
55.	3	2.44	96.75
60.	2	1.63	98.37
OVER 60.	2	1.63	100.00

APPOINTMENT SYSTEM 7 (RUN 4)

AVERAGE PATIENT WAITING TIME	= 25.66 MIN
AVERAGE LENGTH OF IDLE TIME	= 3.73 MIN
AVERAGE DOCTOR IDLE TIME	= 1.61 MIN
MEAN EARLY AT OF PATIENT	= 11.26
MEAN CONSULTATION TIME	= 6.96
LENGTH OF CLINICAL SESSION	= 237.61
NUMBER OF WALK-IN PATIENTS	= 11
MEAN NUMBER OF DOCTORS AVAIL	= 4.63

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	7	5.34	5.34
10.	9	6.87	12.21
15.	6	4.58	16.79
20.	13	9.92	26.72
25.	22	16.79	43.51
30.	25	19.08	62.60
35.	27	20.61	83.21
40.	12	9.16	92.37
45.	6	4.58	96.95
50.	2	1.53	98.47
55.	1	0.76	99.24
60.	0	0.0	99.24
OVER 60.	1	0.76	100.00

APPOINTMENT SYSTEM 7 (RUN 5)

AVERAGE PATIENT WAITING TIME	=	24.01 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.0 MIN
AVERAGE DOCTOR IDLE TIME	=	0.0 MIN
MEAN EARLY AT OF PATIENT	=	11.97
MEAN CONSULTATION TIME	=	5.98
LENGTH OF CLINICAL SESSION	=	235.09
NUMBER OF WALK-IN PATIENTS	=	4
MEAN NUMBER OF DOCTORS AVAIL	=	3.50

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	4	3.23	3.23
10.	12	9.68	12.90
15.	12	9.68	22.58
20.	16	12.90	35.48
25.	21	16.94	52.42
30.	24	19.35	71.77
35.	21	16.94	88.71
40.	7	5.65	94.35
45.	3	2.42	96.77
50.	1	0.81	97.58
55.	2	1.61	99.19
60.	1	0.81	100.00
OVER 60.	0	0.0	100.00

APPOINTMENT SYSTEM 7 (RUN 7)

AVERAGE PATIENT WAITING TIME	=	27.02 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.0 MIN
AVERAGE DOCTOR IDLE TIME	=	0.0 MIN
MEAN EARLY AT OF PATIENT	=	11.96
MEAN CONSULTATION TIME	=	6.15
LENGTH OF CLINICAL SESSION	=	253.45
NUMBER OF WALK-IN PATIENTS	=	7
MEAN NUMBER OF DOCTORS AVAIL	=	3.50

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	1	0.79	0.79
10.	4	3.15	3.94
15.	7	5.51	9.45
20.	22	17.32	26.77
25.	25	19.69	46.46
30.	20	15.75	62.20
35.	19	14.96	77.17
40.	16	12.60	89.76
45.	10	7.87	97.64
50.	3	2.36	100.00
55.	0	0.0	100.00
60.	0	0.0	100.00
OVER 60.	0	0.0	100.00

APPOINTMENT SYSTEM 7 (RUN 8)

AVERAGE PATIENT WAITING TIME	= 14.49 MIN
AVERAGE LENGTH OF IDLE TIME	= 2.52 MIN
AVERAGE DOCTOR IDLE TIME	= 13.40 MIN
MEAN EARLY AT OF PATIENT	= 10.85
MEAN CONSULTATION TIME	= 6.70
LENGTH OF CLINICAL SESSION	= 232.18
NUMBER OF WALK-IN PATIENTS	= 2
MEAN NUMBER OF DOCTORS AVAIL	= 4.14

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	52	42.62	42.62
10.	7	5.74	48.36
15.	9	7.38	55.74
20.	10	8.20	63.93
25.	11	9.02	72.95
30.	8	6.56	79.51
35.	15	12.30	91.80
40.	5	4.10	95.90
45.	2	1.64	97.54
50.	2	1.64	99.18
55.	1	0.82	100.00
60.	0	0.0	100.00
OVER 60.	0	0.0	100.00

APPOINTMENT SYSTEM 7 (RUN 9)

AVERAGE PATIENT WAITING TIME	=	49.26 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.0 MIN
AVERAGE DOCTOR IDLE TIME	=	0.0 MIN
MEAN EARLY AT OF PATIENT	=	11.36
MEAN CONSULTATION TIME	=	6.19
LENGTH OF CLINICAL SESSION	=	258.45
NUMBER OF WALK-IN PATIENTS	=	7
MEAN NUMBER OF DOCTORS AVAIL	=	3.56

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	0	0.0	0.0
10.	0	0.0	0.0
15.	3	2.36	2.36
20.	2	1.57	3.94
25.	4	3.15	7.09
30.	9	7.09	14.17
35.	8	6.30	20.47
40.	15	11.81	32.28
45.	9	7.09	39.37
50.	21	16.54	55.91
55.	16	12.60	68.50
60.	8	6.30	74.80
OVER 60.	32	25.20	100.00

APPOINTMENT SYSTEM 7 (RUN 10)

AVERAGE PATIENT WAITING TIME	=	26.19 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.0 MIN
AVERAGE DOCTOR IDLE TIME	=	0.0 MIN
MEAN EARLY AT OF PATIENT	=	11.98
MEAN CONSULTATION TIME	=	7.00
LENGTH OF CLINICAL SESSION	=	257.76
NUMBER OF WALK-IN PATIENTS	=	4
MEAN NUMBER OF DOCTORS AVAIL	=	3.67

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	6	4.84	4.84
10.	10	8.06	12.90
15.	9	7.26	20.16
20.	17	13.71	33.87
25.	14	11.29	45.16
30.	15	12.10	57.26
35.	19	15.32	72.58
40.	17	13.71	86.29
45.	8	6.45	92.74
50.	5	4.03	96.77
55.	4	3.23	100.00
60.	0	0.0	100.00
OVER 60.	0	0.0	100.00

APPOINTMENT SYSTEM 7 (RUN 11)

AVERAGE PATIENT WAITING TIME	= 29.02 MIN
AVERAGE LENGTH OF IDLE TIME	= 0.0 MIN
AVERAGE DOCTOR IDLE TIME	= 0.0 MIN
MEAN EARLY AT OF PATIENT	= 10.86
MEAN CONSULTATION TIME	= 7.29
LENGTH OF CLINICAL SESSION	= 249.88
NUMBER OF WALK-IN PATIENTS	= 5
MEAN NUMBER OF DOCTORS AVAIL	= 3.89

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	0	0.0	0.0
10.	2	1.60	1.60
15.	7	5.60	7.20
20.	22	17.60	24.80
25.	19	15.20	40.00
30.	22	17.60	57.60
35.	14	11.20	68.80
40.	20	16.00	84.80
45.	6	4.80	89.60
50.	9	7.20	96.60
55.	2	1.60	98.40
60.	2	1.60	100.00
OVER 60.	0	0.0	100.00

APPOINTMENT SYSTEM 7 (RUN 12)

AVERAGE PATIENT WAITING TIME =	43.47 MIN
AVERAGE LENGTH OF IDLE TIME =	0.0 MIN
AVERAGE DOCTOR IDLE TIME =	0.0 MIN
MEAN EARLY AT OF PATIENT =	9.83
MEAN CONSULTATION TIME =	6.82
LENGTH OF CLINICAL SESSION =	282.33
NUMBER OF WALK-IN PATIENTS =	5
MEAN NUMBER OF DOCTORS AVAIL =	3.44

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	0	0.0	0.0
10.	0	0.0	0.0
15.	0	0.0	0.0
20.	1	0.80	0.80
25.	14	11.20	12.00
30.	8	6.40	18.40
35.	19	15.20	33.60
40.	18	14.40	48.00
45.	13	10.40	58.40
50.	15	12.00	70.40
55.	13	10.40	80.80
60.	8	6.40	87.20
OVER 60.	16	12.80	100.00

APPOINTMENT SYSTEM 7 (RUN 13)

AVERAGE PATIENT WAITING TIME	= 14.65 MIN
AVERAGE LENGTH OF IDLE TIME	= 2.41 MIN
AVERAGE DOCTOR IDLE TIME	= 10.83 MIN
MEAN EARLY AT OF PATIENT	= 10.66
MEAN CONSULTATION TIME	= 6.60
LENGTH OF CLINICAL SESSION	= 254.75
NUMBER OF WALK-IN PATIENTS	= 5
MEAN NUMBER OF DOCTORS AVAIL	= 3.78

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	34	27.20	27.20
10.	19	15.20	42.40
15.	14	11.20	53.60
20.	16	12.80	66.40
25.	13	10.40	76.80
30.	16	12.80	89.60
35.	10	8.00	97.60
40.	0	0.0	97.60
45.	2	1.60	99.20
50.	1	0.80	100.00
55.	0	0.0	100.00
60.	0	0.0	100.00
OVER 60.	0	0.0	100.00

APPOINTMENT SYSTEM 7 (RUN 14)

AVERAGE PATIENT WAITING TIME	= 25.85 MIN
AVERAGE LENGTH OF IDLE TIME	= 0.0 MIN
AVERAGE DOCTOR IDLE TIME	= 0.0 MIN
MEAN EARLY AT OF PATIENT	= 11.67
MEAN CONSULTATION TIME	= 6.58
LENGTH OF CLINICAL SESSION	= 247.36
NUMBER OF WALK-IN PATIENTS	= 5
MEAN NUMBER OF DOCTORS AVAIL	= 3.63

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	13	10.40	10.40
10.	11	8.80	19.20
15.	12	9.60	28.80
20.	16	12.80	41.60
25.	12	9.60	51.20
30.	15	12.00	63.20
35.	6	4.80	68.00
40.	13	10.40	78.40
45.	9	7.20	85.60
50.	7	5.60	91.20
55.	6	4.80	96.00
60.	3	2.40	98.40
OVER 60.	2	1.60	100.00

APPOINTMENT SYSTEM 7 (RUN 15)

AVERAGE PATIENT WAITING TIME	=	40.74 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.0 MIN
AVERAGE DOCTOR IDLE TIME	=	0.0 MIN
MEAN EARLY AT OF PATIENT	=	10.99
MEAN CONSULTATION TIME	=	6.34
LENGTH OF CLINICAL SESSION	=	276.36
NUMBER OF WALK-IN PATIENTS	=	9
MEAN NUMBER OF DOCTORS AVAIL	=	3.67

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	0	0.0	0.0
10.	2	1.55	1.55
15.	3	2.33	3.88
20.	7	5.43	9.30
25.	12	9.30	18.60
30.	7	5.43	24.03
35.	12	9.30	33.33
40.	18	13.95	47.29
45.	13	10.08	57.36
50.	18	13.95	71.32
55.	11	8.53	79.84
60.	14	10.85	90.70
OVER 60.	12	9.30	100.00

APPOINTMENT SYSTEM 7 (RUN 16)

AVERAGE PATIENT WAITING TIME	= 60.84 MIN
AVERAGE LENGTH OF IDLE TIME	= 0.0 MIN
AVERAGE DOCTOR IDLE TIME	= 0.0 MIN
MEAN EARLY AT OF PATIENT	= 12.32
MEAN CONSULTATION TIME	= 7.34
LENGTH OF CLINICAL SESSION	= 293.63
NUMBER OF WALK-IN PATIENTS	= 4
MEAN NUMBER OF DOCTORS AVAIL	= 3.40

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	0	0.0	0.0
10.	0	0.0	0.0
15.	0	0.0	0.0
20.	3	2.42	2.42
25.	2	1.61	4.03
30.	2	1.61	5.65
35.	5	4.03	9.68
40.	6	4.84	14.52
45.	5	4.03	18.55
50.	10	8.06	26.61
55.	11	8.87	35.48
60.	14	11.29	46.77
OVER 60.	66	53.23	100.00

APPOINTMENT SYSTEM 7 (RUN 17)

AVERAGE PATIENT WAITING TIME	= 30.64	MIN
AVERAGE LENGTH OF IDLE TIME	= 0.0	MIN
AVERAGE DOCTOR IDLE TIME	= 0.0	MIN
MEAN EARLY AT OF PATIENT	= 11.31	
MEAN CONSULTATION TIME	= 6.82	
LENGTH OF CLINICAL SESSION	= 265.54	
NUMBER OF WALK-IN PATIENTS	= 6	
MEAN NUMBER OF DOCTORS AVAIL	= 3.78	

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	1	0.79	0.79
10.	1	0.79	1.59
15.	1	0.79	2.38
20.	15	11.90	14.29
25.	20	15.87	30.16
30.	21	16.67	46.83
35.	28	22.22	69.05
40.	21	16.67	85.71
45.	8	6.35	92.06
50.	6	4.76	96.83
55.	4	3.17	100.00
60.	0	0.0	100.00
OVER 60.	0	0.0	100.00

APPOINTMENT SYSTEM 7 (RUN 18)

AVERAGE PATIENT WAITING TIME	= 27.92 MIN
AVERAGE LENGTH OF IDLE TIME	= 0.0 MIN
AVERAGE DOCTOR IDLE TIME	= 0.0 MIN
MEAN EARLY AT OF PATIENT	= 10.66
MEAN CONSULTATION TIME	= 7.56
LENGTH OF CLINICAL SESSION	= 289.24
NUMBER OF WALK-IN PATIENTS	= 5
MEAN NUMBER OF DOCTORS AVAIL	= 3.50

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	2	1.60	1.60
10.	4	3.20	4.80
15.	11	8.80	13.60
20.	18	14.40	28.00
25.	25	20.00	48.00
30.	21	16.80	64.80
35.	11	8.80	73.60
40.	9	7.20	80.80
45.	10	8.00	88.80
50.	5	4.00	92.80
55.	5	4.00	96.80
60.	3	2.40	99.20
OVER 60.	1	0.80	100.00

APPOINTMENT SYSTEM 7 (RUN 19)

AVERAGE PATIENT WAITING TIME	= 13.88 MIN
AVERAGE LENGTH OF IDLE TIME	= 3.38 MIN
AVERAGE DOCTOR IDLE TIME	= 9.01 MIN
MEAN EARLY AT OF PATIENT	= 10.24
MEAN CONSULTATION TIME	= 6.57
LENGTH OF CLINICAL SESSION	= 224.90
NUMBER OF WALK-IN PATIENTS	= 6
MEAN NUMBER OF DOCTORS AVAIL	= 4.13

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	46	36.51	36.51
10.	17	13.49	50.00
15.	7	5.56	55.56
20.	11	8.73	64.29
25.	14	11.11	75.40
30.	19	15.08	90.48
35.	3	2.38	92.86
40.	7	5.56	98.41
45.	2	1.59	100.00
50.	0	0.0	100.00
55.	0	0.0	100.00
60.	0	0.0	100.00
OVER 60.	0	0.0	100.00

APPOINTMENT SYSTEM 7 (RUN 20)

AVERAGE PATIENT WAITING TIME	=	36.44 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.0 MIN
AVERAGE DOCTOR IDLE TIME	=	0.0 MIN
MEAN EARLY AT OF PATIENT	=	9.54
MEAN CONSULTATION TIME	=	7.06
LENGTH OF CLINICAL SESSION	=	273.85
NUMBER OF WALK-IN PATIENTS	=	6
MEAN NUMBER OF DOCTORS AVAIL	=	3.67

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	3	2.38	2.38
10.	4	3.17	5.56
15.	6	4.76	10.32
20.	5	3.97	14.29
25.	16	12.70	26.98
30.	18	14.29	41.27
35.	10	7.94	49.21
40.	8	6.35	55.56
45.	12	9.52	65.08
50.	12	9.52	74.60
55.	12	9.52	84.13
60.	14	11.11	95.24
OVER 60.	6	4.76	100.00

APPOINTMENT SYSTEM 7 (RUN 21)

AVERAGE PATIENT WAITING TIME = 26.68 MIN
AVERAGE LENGTH OF IDLE TIME = 2.57 MIN
AVERAGE DOCTOR IDLE TIME = 6.71 MIN
MEAN EARLY AT OF PATIENT = 14.07
MEAN CONSULTATION TIME = 6.76
LENGTH OF CLINICAL SESSION = 268.12
NUMBER OF WALK-IN PATIENTS = 4
MEAN NUMBER OF DOCTORS AVAIL = 3.44

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	18	14.52	14.52
10.	4	3.23	17.74
15.	9	7.26	25.00
20.	14	11.29	36.29
25.	8	6.45	42.74
30.	12	9.68	52.42
35.	22	17.74	70.16
40.	13	10.48	80.65
45.	9	7.26	87.90
50.	8	6.45	94.35
55.	4	3.23	97.58
60.	2	1.61	99.19
OVER 60.	1	0.81	100.00

APPOINTMENT SYSTEM 7 (RUN 22)

AVERAGE PATIENT WAITING TIME	= 13.70 MIN
AVERAGE LENGTH OF IDLE TIME	= 4.78 MIN
AVERAGE DOCTOR IDLE TIME	= 11.94 MIN
MEAN EARLY AT OF PATIENT	= 11.95
MEAN CONSULTATION TIME	= 6.56
LENGTH OF CLINICAL SESSION	= 248.76
NUMBER OF WALK-IN PATIENTS	= 6
MEAN NUMBER OF DOCTORS AVAIL	= 4.00

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	40	31.75	31.75
10.	17	13.49	45.24
15.	21	16.67	61.90
20.	7	5.56	67.46
25.	19	15.08	82.54
30.	10	7.94	90.48
35.	4	3.17	93.65
40.	6	4.76	98.41
45.	2	1.59	100.00
50.	0	0.0	100.00
55.	0	0.0	100.00
60.	0	0.0	100.00
OVER 60.	0	0.0	100.00

APPOINTMENT SYSTEM 7 (RUN 23)

AVERAGE PATIENT WAITING TIME	= 43.14 MIN
AVERAGE LENGTH OF IDLE TIME	= 0.0 MIN
AVERAGE DOCTOR IDLE TIME	= 0.0 MIN
MEAN EARLY AT OF PATIENT	= 11.67
MEAN CONSULTATION TIME	= 6.62
LENGTH OF CLINICAL SESSION	= 280.73
NUMBER OF WALK-IN PATIENTS	= 8
MEAN NUMBER OF DOCTORS AVAIL	= 3.50

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	0	0.0	0.0
10.	4	3.13	3.13
15.	2	1.56	4.69
20.	6	4.69	9.38
25.	14	10.94	20.31
30.	18	14.06	34.38
35.	9	7.03	41.41
40.	11	8.59	50.00
45.	6	4.69	54.69
50.	11	8.59	63.28
55.	12	9.38	72.66
60.	3	2.34	75.00
OVE.. 60.	32	25.00	100.00

APPOINTMENT SYSTEM 7 (RUN 24)

AVERAGE PATIENT WAITING TIME	= 23.59 MIN
AVERAGE LENGTH OF IDLE TIME	= 0.0 MIN
AVERAGE DOCTOR IDLE TIME	= 0.0 MIN
MEAN EARLY AT OF PATIENT	= 9.75
MEAN CONSULTATION TIME	= 7.32
LENGTH OF CLINICAL SESSION	= 271.15
NUMBER OF WALK-IN PATIENTS	= 6
MEAN NUMBER OF DOCTORS AVAIL	= 3.67

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	6	4.76	4.76
10.	8	6.35	11.11
15.	11	8.73	19.84
20.	27	21.43	41.27
25.	26	20.63	61.90
30.	20	15.87	77.78
35.	9	7.14	84.92
40.	5	3.97	88.89
45.	6	4.76	93.65
50.	1	0.79	94.44
55.	4	3.17	97.62
60.	1	0.79	98.41
OVER 60.	2	1.59	100.00

APPOINTMENT SYSTEM 7 (RUN 25)

AVERAGE PATIENT WAITING TIME	=	34.44 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.0 MIN
AVERAGE DOCTOR IDLE TIME	=	0.0 MIN
MEAN EARLY AT OF PATIENT	=	11.60
MEAN CONSULTATION TIME	=	6.80
LENGTH OF CLINICAL SESSION	=	262.15
NUMBER OF WALK-IN PATIENTS	=	4
MEAN NUMBER OF DOCTORS AVAIL	=	3.67

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	3	2.42	2.42
10.	3	2.42	4.84
15.	9	7.26	12.10
20.	8	6.45	18.55
25.	13	10.48	29.03
30.	10	8.06	37.10
35.	8	6.45	43.55
40.	17	13.71	57.26
45.	21	16.94	74.19
50.	20	16.13	90.32
55.	6	4.84	95.16
60.	2	1.61	96.77
OVER 60.	4	3.23	100.00

APPENDIX E

APPOINTMENT SYSTEMS (1-12) CUMULATED OUTPUT

APPOINTMENT SYSTEM 1(ALL 25 RUNS COMBINED)

AVERAGE PATIENT WAITING TIME	=	9.87 MIN
AVERAGE LENGTH OF IDLE TIME	=	4.80 MIN
AVERAGE DOCTOR IDLE TIME	=	40.63 MIN
MEAN EARLY AT OF PATIENT	=	0.0
MEAN CONSULTATION TIME	=	0.0
LENGTH OF CLINICAL SESSION	=	0.0
NUMBER OF WALK-IN PATIENTS	=	0
MEAN NUMBER OF DOCTORS AVAIL	=	0.0

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	1634	51.30	51.30
10.	384	12.06	63.36
15.	334	10.49	73.85
20.	221	6.94	80.78
25.	207	6.50	87.28
30.	141	4.43	91.71
35.	99	3.11	94.82
40.	72	2.26	97.08
45.	25	0.78	97.86
50.	35	1.10	98.96
55.	16	0.50	99.47
60.	13	0.41	99.87
OVER 60.	4	0.13	100.00

APPOINTMENT SYSTEM 2 (ALL 25 RUNS COMBINED)

AVERAGE PATIENT WAITING TIME	= 15.05 MIN
AVERAGE LENGTH OF IDLE TIME	= 2.79 MIN
AVERAGE DOCTOR IDLE TIME	= 18.37 MIN
MEAN EARLY AT OF PATIENT	= 0.0
MEAN CONSULTATION TIME	= 0.0
LENGTH OF CLINICAL SESSION	= 0.0
NUMBER OF WALK-IN PATIENTS	= 0
MEAN NUMBER OF DOCTORS AVAIL	= 0.0

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	1142	36.09	36.09
10.	382	12.07	48.17
15.	335	10.59	58.75
20.	300	9.48	68.24
25.	257	8.12	76.36
30.	203	6.42	82.77
35.	181	5.72	88.50
40.	126	3.98	92.48
45.	81	2.56	95.04
50.	43	1.36	96.40
55.	45	1.42	97.82
60.	28	0.88	98.70
OVER 60.	41	1.30	100.00

APPOINTMENT SYSTEM 3(ALL 25 RUNS COMBINED)

AVERAGE PATIENT WAITING TIME	= 28.07 MIN
AVERAGE LENGTH OF IDLE TIME	= 1.12 MIN
AVERAGE DOCTOR IDLE TIME	= 4.29 MIN
MEAN EARLY AT OF PATIENT	= 0.0
MEAN CONSULTATION TIME	= 0.0
LENGTH OF CLINICAL SESSION	= 0.0
NUMBER OF WALK-IN PATIENTS	= 0
MEAN NUMBER OF DOCTORS AVAIL	= 0.0

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	454	14.42	14.42
10.	282	8.96	23.38
15.	304	9.66	33.04
20.	280	8.89	41.93
25.	300	9.53	51.46
30.	282	8.96	60.42
35.	235	7.47	67.88
40.	191	6.07	73.95
45.	181	5.75	79.70
50.	132	4.19	83.89
55.	112	3.56	87.45
60.	90	2.86	90.31
OVER 60.	305	9.69	100.00

APPOINTMENT SYSTEM 4(ALL 25 RUNS COMBINED)

AVERAGE PATIENT WAITING TIME	=	36.91 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.40 MIN
AVERAGE DOCTOR IDLE TIME	=	1.34 MIN
MEAN EARLY AT OF PATIENT	=	0.0
MEAN CONSULTATION TIME	=	0.0
LENGTH OF CLINICAL SESSION	=	0.0
NUMBER OF WALK-IN PATIENTS	=	0
MEAN NUMBER OF DOCTORS AVAIL	=	0.0

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	232	7.40	7.40
10.	170	5.42	12.82
15.	222	7.08	19.90
20.	247	7.88	27.78
25.	282	9.00	36.78
30.	292	9.31	46.09
35.	259	8.26	54.35
40.	192	6.12	60.48
45.	208	6.63	67.11
50.	170	5.42	72.54
55.	154	4.91	77.45
60.	141	4.50	81.95
OVER 60.	566	18.05	100.00

APPOINTMENT SYSTEM 5(ALL 25 RUNS COMBINED)

AVERAGE PATIENT WAITING TIME	=	38.62 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.35 MIN
AVERAGE DOCTOR IDLE TIME	=	0.39 MIN
MEAN EARLY AT OF PATIENT	=	0.0
MEAN CONSULTATION TIME	=	0.0
LENGTH OF CLINICAL SESSION	=	0.0
NUMBER OF WALK-IN PATIENTS	=	0
MEAN NUMBER OF DOCTORS AVAIL	=	0.0

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	211	6.77	6.77
10.	219	7.03	13.80
15.	228	7.31	21.11
20.	252	8.08	29.19
25.	310	9.95	39.14
30.	288	9.24	48.38
35.	224	7.19	55.57
40.	185	5.94	61.50
45.	162	5.20	66.70
50.	160	5.13	71.83
55.	121	3.88	75.71
60.	104	3.34	79.05
OVER 60.	653	20.95	100.00

APPOINTMENT SYSTEM 6(ALL 25 RUNS COMBINED)

AVERAGE PATIENT WAITING TIME	=	16.51 MIN
AVERAGE LENGTH OF IDLE TIME	=	3.23 MIN
AVERAGE DOCTOR IDLE TIME	=	22.49 MIN
MEAN EARLY AT OF PATIENT	=	0.0
MEAN CONSULTATION TIME	=	0.0
LENGTH OF CLINICAL SESSION	=	0.0
NUMBER OF WALK-IN PATIENTS	=	0
MEAN NUMBER OF DOCTORS AVAIL	=	0.0

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	1080	33.81	33.81
10.	335	10.49	44.30
15.	341	10.68	54.98
20.	296	9.27	64.25
25.	273	8.55	72.79
30.	213	6.67	79.46
35.	182	5.70	85.16
40.	145	4.54	89.70
45.	105	3.29	92.99
50.	83	2.60	95.59
55.	46	1.44	97.03
60.	42	1.31	98.34
OVER 60.	53	1.66	100.00

APPOINTMENT SYSTEM 7(ALL 25 RUNS COMBINED)

AVERAGE PATIENT WAITING TIME	= 28.87 MIN
AVERAGE LENGTH OF IDLE TIME	= 1.01 MIN
AVERAGE DOCTOR IDLE TIME	= 2.82 MIN
MEAN EARLY AT OF PATIENT	= 0.0
MEAN CONSULTATION TIME	= 0.0
LENGTH OF CLINICAL SESSION	= 0.0
NUMBER OF WALK-IN PATIENTS	= 0
MEAN NUMBER OF DOCTORS AVAIL	= 0.0

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	276	8.80	8.80
10.	178	5.68	14.48
15.	216	6.89	21.37
20.	354	11.29	32.66
25.	387	12.34	45.01
30.	378	12.06	57.07
35.	335	10.69	67.75
40.	296	9.44	77.19
45.	175	5.58	82.78
50.	166	5.30	88.07
55.	118	3.76	91.83
60.	78	2.49	94.32
OVER 60.	178	5.68	100.00

APPOINTMENT SYSTEM 8(ALL 25 RUNS COMBINED)

AVERAGE PATIENT WAITING TIME	=	44.18 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.42 MIN
AVERAGE DOCTOR IDLE TIME	=	0.20 MIN
MEAN EARLY AT OF PATIENT	=	0.0
MEAN CONSULTATION TIME	=	0.0
LENGTH OF CLINICAL SESSION	=	0.0
NUMBER OF WALK-IN PATIENTS	=	0
MEAN NUMBER OF DOCTORS AVAIL	=	0.0

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	82	2.63	2.63
10.	120	3.85	6.49
15.	172	5.52	12.01
20.	238	7.64	19.65
25.	258	8.29	27.94
30.	293	9.41	37.35
35.	284	9.12	46.47
40.	272	8.73	55.20
45.	184	5.91	61.11
50.	147	4.72	65.83
55.	160	5.14	70.97
60.	129	4.14	75.11
OVER 60.	775	24.89	100.00

APPOINTMENT SYSTEM 9(ALL 25 RUNS COMBINED)

AVERAGE PATIENT WAITING TIME	= 12.89 MIN
AVERAGE LENGTH OF IDLE TIME	= 4.40 MIN
AVERAGE DOCTOR IDLE TIME	= 35.23 MIN
MEAN EARLY AT OF PATIENT	= 0.0
MEAN CONSULTATION TIME	= 0.0
LENGTH OF CLINICAL SESSION	= 0.0
NUMBER OF WALK-IN PATIENTS	= 0
MEAN NUMBER OF DOCTORS AVAIL	= 0.0

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	1312	41.57	41.57
10.	355	11.25	52.82
15.	300	9.51	62.33
20.	309	9.79	72.12
25.	276	8.75	80.86
30.	170	5.39	86.25
35.	157	4.97	91.22
40.	106	3.36	94.58
45.	74	2.34	96.93
50.	52	1.65	98.57
55.	31	0.98	99.56
60.	9	0.29	99.84
OVER 60.	5	0.16	100.00

APPOINTMENT SYSTEM 10(ALL 25 RUNS COMBINED)

AVERAGE PATIENT WAITING TIME	=	26.90 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.93 MIN
AVERAGE DOCTOR IDLE TIME	=	2.23 MIN
MEAN EARLY AT OF PATIENT	=	0.0
MEAN CONSULTATION TIME	=	0.0
LENGTH OF CLINICAL SESSION	=	0.0
NUMBER OF WALK-IN PATIENTS	=	0
MEAN NUMBER OF DOCTORS AVAIL	=	0.0

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	297	9.51	9.51
10.	240	7.68	17.19
15.	322	10.31	27.50
20.	367	11.75	39.24
25.	386	12.36	51.60
30.	426	13.64	65.24
35.	302	9.67	74.90
40.	194	6.21	81.11
45.	128	4.10	85.21
50.	119	3.81	89.02
55.	64	2.05	91.07
60.	63	2.02	93.09
OVER 60.	216	6.91	100.00

APPOINTMENT SYSTEM 11 (ALL 25 RUNS COMBINED)

AVERAGE PATIENT WAITING TIME	=	43.49 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.05 MIN
AVERAGE DOCTOR IDLE TIME	=	0.17 MIN
MEAN EARLY AT OF PATIENT	=	0.0
MEAN CONSULTATION TIME	=	0.0
LENGTH OF CLINICAL SESSION	=	0.0
NUMBER OF WALK-IN PATIENTS	=	0
MEAN NUMBER OF DOCTORS AVAIL	=	0.0

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	66	2.11	2.11
10.	81	2.60	4.71
15.	121	3.88	8.59
20.	195	6.25	14.83
25.	273	8.75	23.58
30.	295	9.45	33.03
35.	331	10.61	43.64
40.	280	8.97	52.61
45.	237	7.59	60.21
50.	225	7.21	67.41
55.	193	6.18	73.60
60.	151	4.84	78.44
OVER 60.	673	21.56	100.00

APPOINTMENT SYSTEM 12 (ALL 25 RUNS COMBINED)

AVERAGE PATIENT WAITING TIME	=	81.40 MIN
AVERAGE LENGTH OF IDLE TIME	=	0.0 MIN
AVERAGE DOCTOR IDLE TIME	=	0.0 MIN
MEAN EARLY AT OF PATIENT	=	0.0
MEAN CONSULTATION TIME	=	0.0
LENGTH OF CLINICAL SESSION	=	0.0
NUMBER OF WALK-IN PATIENTS	=	0
MEAN NUMBER OF DOCTORS AVAIL	=	0.0

INDIVIDUAL WAITING TIMES

UPPER LIMIT	OBS. FREQ	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
5.	0	0.0	0.0
10.	7	0.23	0.23
15.	18	0.59	0.81
20.	28	0.91	1.73
25.	115	3.75	5.47
30.	168	5.47	10.94
35.	169	5.50	16.45
40.	130	4.23	20.68
45.	131	4.27	24.95
50.	131	4.27	29.22
55.	127	4.14	33.36
60.	125	4.07	37.43
OVER 60.	1921	62.57	100.00

VITA

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